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The Road to the Future of Cars: Opportunities and Key Features for Car Sharing Services

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Abstract

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by Lennard VAN DEN BERG

The current market share of car sharing does not match the potential estimated in literature. In this thesis, various unexploited opportunities for car sharing, such as integration with public transportation and service of rural areas, have been identified and explored. The goal of the study is to find features that would increase the utilisation and acceptance of car sharing as a capable mobility alternative. Three existing information sources are analysed. Besides literature, online reviews and a daily mobility dataset are chosen, as these sources are not exploited in other research yet and are easily accessible. The insights that are gained into mobility behaviour and satisfaction, highlight the difficulties to create a homogeneous car sharing service to attract and satisfy customers in every available location. A list of features is created in which trip type, dedicated parking spots and availability are found to require priority. The provided features and concepts can be used by different parties, such as car sharing companies, governments, and policy makers, to improve car sharing or mobility in general.

Keywords: Car sharing, Shared vehicle fleet, Key design features, Public transportation, Rural

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List of Abbreviations

B2C	**B**usiness **2**(to) **C**onsumer
CBS	**C**entraal **B**ureau voor de **S**tatistiek
FMLM	**F**irst **M**ile **L**ast **M**ile
NS	**N**ederlandse **S**poorwegen (Dutch railway company)
OViN	**O**nderzoek **V**erplaatsingen **in** **N**ederland
P2P	**P**eer **2**(to) **P**eer
PT	**P**ublic **T**ransportation
VKT	**V**ehicle **K**ilometres **T**ravelled

Chapter 1

Introduction

This thesis is written as part of the Information Sciences curriculum at the Radboud University, Nijmegen, the Netherlands. The research is performed at a startup company called Going Dutch, located in Lochem, the Netherlands. With the knowledge gained during years of working with transportation planning, they are creating a unique car sharing service. Various untapped growth opportunities for car sharing have been identified by Going Dutch and are used to define the subject of this thesis.

1.1 Motivation

Cars are one of the most used mobility types in today's society. They provide a comfortable, flexible and private way of travelling. Although private cars have many benefits, downsides also exist. Most cars are stationary for a significant portion of the day and car ownership is expensive. As the number of cars on the road grows, congestion, parking issues and CO_2 emission also increase.

A way to address these issues could be car sharing, a type of car rental for people who want to rent a car to travel a short distance or for a short period of time. Car sharing provides its users with the benefits of a private vehicle, but removes fixed and unexpected costs, and delegates maintenance and repair responsibilities. The advantages are not limited to individual car sharing users. Car sharing increases the average daily usage time per car and decreases the time spent stationary, which leads to less cars needed for everybody to fulfil their travel needs. Additionally, car sharing organisations use fuel efficient vehicles or even electrical vehicles, which is also beneficial for the environment.

This sounds very promising and studies conducted at the end of the 20th century estimated that car sharing has a great potential. One study predicted a car sharing market share of 9% in Austria (Steininger et al., 1996), while another study predicted a potential of 600,000 customers for the Mobility Switzerland service (Muheim and Reinhardt, 1999). Both studies turned out to be off by more than a factor of five. Why is interest in car sharing not translated into usage?

1.2 Problem definition

Although the concept of car sharing shows potential, car sharing has not been as widely adopted as was previously predicted. It is not for a lack of trying, as in Germany alone there are over 100 car sharing companies (Loose, 2010). Various approaches have been tried, but more opportunities can be distinguished to improve a car sharing service and capture a larger market share.

For long distance commuters who travel by private car, car sharing is not interesting because of the cost and the restriction of some services to return the car to the pickup location. Car sharing is ideal to facilitate short trips, for example, for shopping or social activities, and to replace a second car.

Integration with PT is lacking for car sharing. In theory, car sharing would be ideal for the so called 'first mile/last mile' (FMLM) problem of a PT journey, as shared cars could be used to travel to or from a bus or train station. Current restrictions limiting integration can be identified, such as returning the car to the pickup location as well as the uncertainty of availability. The PT coverage in urban areas is often better than in rural areas resulting in a FMLM less than one mile. While in rural areas, this might be multiple miles.

Most research conducted related to car sharing markets look at urban areas because a higher population density leads to more demand and a bigger market. With the decline of PT coverage in rural areas in the Netherlands, these areas might become more interested in and interesting for car sharing services.

With the recent technological advancement of self-driving cars, new opportunities arise for car sharing companies. The possibility for cars to relocate themselves, opens the ability to turn car sharing into an autonomous taxi service. The transition to autonomous cars will not likely happen overnight, therefore car sharing companies could already prepare to ease the transition and have the infrastructure in place to support such a taxi system.

Given these opportunities are yet unexploited, research is needed to investigate the feasibility of implementation.

1.3 Research objective

This study aims to find features for car sharing services which would increase their utilisation and acceptance as a capable mobility alternative. A feature is a distinctive attribute or element which, when implemented correctly, profits/benefits (or at least not harms) at least one stakeholder group. The considered stakeholders involved with car sharing are users, car sharing companies, governments, and the environment. This thesis takes the perspective of users to identify wanted and unwanted features.

1.4 Research approach

Three existing information sources are explored to analyse and synthesise information regarding people's implicit and explicit mobility preferences. These sources are chosen for their accessibility, and for not being (fully) exploited yet. The first information source is literature. Literature is examined, and findings are analysed and discussed. The goal is to establish a knowledge base about what has already been researched in the field of car sharing and related people transportation. The focus lies on both discovering car sharing features as well as PT and private car features. Secondly, current experiences with car sharing services are analysed by looking at online reviews. Within the reviews, user appreciation of the described feature is studied. Thirdly, travel behaviour is analysed to confirm, contradict and extrapolate user desired features. Finally, the gathered features are verified against each other and the interests of other stakeholders, to create an overview of compatible and conflicting features.

1.5 Research question

With the research objective and approach defined, the research question that this thesis will try to answer can be formulated.

What are the key design features of a shared vehicle fleet to stimulate adoption and social support amongst the general public?

As indicated in the motivation section of this chapter, car sharing has not grown as fast as estimated. Different car sharing companies have had varying degrees of success, but the number of users remains a small portion of the total population. To exploit all the advantages of car sharing, a larger user base is needed. To find how more people can be attracted to use car sharing (adoption) and how to shape a positive public opinion (social support) about car sharing, car sharing services need to fit the needs of society. These needs should be reflected in what features are implemented in car sharing services. This research focuses on finding these features in literature, reviews and travel behaviour.

A vehicle fleet is defined as a group of motor vehicles owned or leased by a business, government agency or other organization rather than by an individual or family.

1.6 Roadmap

The thesis' structure is derived from the three information sources described in the research approach section. Each source is discussed in a separate chapter. These chapters have one or two research questions related to the information source they will analyse.

In chapter 2 candidate car sharing features are searched for in literature. In this chapter car sharing literature is analysed to answer the following question: *What kind of candidate car sharing features can be found in literature?* As alternative transportation modes, PT and private car literature is reviewed to distinguish what people want from a transportation service. The question that will be answered is: *Which features found in other forms of people transportation can be applied to car sharing?*

In chapter 3 the online shared experiences of car sharing users are looked at to give insight into how people use and feel about car sharing. The question that will be answered is: *What are the experiences of car sharing users with car sharing and its current features?*

In chapter 4 a dataset with daily mobility in the Netherlands is analysed to differentiate between attitude and behaviour. These two do not always match. Therefore, it is important to not only look at what people think and say, but also how they act. This chapter will answer the following question: *What kind of candidate features can be found in or deduced from travel behaviour?*

In chapter 5 the found candidate features from the three information sources are discussed. They are analysed not only from the perspective of the user, but also from the perspective of the other stakeholders. They are also compared against each other to find conflicting features and whether features depend on each other. Recommendations are formed and the research question is answered.

In chapter 6 conclusions are drawn about the research and the identified car sharing opportunities. The used information sources as well as future research is discussed.

Chapter 2

Literature review

The goal of this chapter is to find candidate car sharing features in literature, by looking at the advantages and disadvantages of different mobility types and analysing the motivation and satisfaction of its users. As mobility types, in addition to car sharing, public transportation (PT) and private cars have been selected to be analysed. PT is chosen, as integration with car sharing is identified to be an unexploited opportunity. Private car is selected to find what motivates people to use a car as mobility type.

First, car sharing is discussed in-depth to create a better understanding of its different implementation forms, users and alternatives. Secondly, PT and private cars are discussed. Thirdly, the future of car sharing is discussed by looking at the potential of autonomous vehicles for car sharing services. Finally, important findings are summarised and found candidate features are discussed.

2.1 Car sharing

Car sharing allows people to rent a vehicle for a short period of time, with the cost of usage based on kilometres and/or time driven.

The first car sharing service is thought to be the Witkar project in the Netherlands (Bendixson and Richards, 1976), based on specially designed electric vehicles. The service had a total of 4000 registered users. A lack of governmental support meant that Witkar would not continue after its experimental phase.

Studies conducted at the end of the 20th century (Steininger et al., 1996; Muheim and Reinhardt, 1999) indicated huge growth potential for car sharing services. This potential has not been transformed into success, with recent research in the Netherlands (TNS Nipo, 2014; Jorritsma and Mobiliteitsbeleid, 2015) showing that only 1% of the Dutch population uses car sharing. TNS Nipo also found that 20% of the respondents is open to car sharing, indicating a still existing potential for the future. In 2015, the Dutch government partnered with private companies, such as Capgemini, Greenwheels, and SnappCar, to create Greendeal 2018 (Rijksoverheid, 2015), an initiative to create more awareness, built and share knowledge, and start pilots and projects to further scale car sharing. These types of collaboration are important for the growth of car sharing. As Terrien et al. (2016) demonstrate, public and private entity collaboration is crucial to create a successful car sharing service. They recommend special organisational structures, appropriate risk allocation and sharing, and building tools to assess profitability.

Car sharing is growing all over Europe (Loose, 2010), besides the Netherlands, other countries such as Switzerland, show above-average growth rates. Both countries were early experimenters with car sharing. However, Germany, also an early experimenter, has not experienced the same growth yet. The implementation and success of car sharing varies in all countries.

Within this section, car sharing will be investigated. First, its advantages and disadvantages are looked at. Secondly, a description of the different types of car sharing is given. Thirdly, the users of car sharing are analysed by demographics, motivation, and usage. Fourthly, alternative services are discussed.

2.1.1 Advantages

The effects of the advantages of car sharing can be divided into three categories: the individual, the transportation infrastructure, and the environment. The advantages for each category will now be discussed.

Individual

A car provides its users mobility in a way that other means of transportation cannot. Cities and road networks are designed around the use of cars. In the mid-nineteenth century, when a car was considered to be a luxury item and less people could afford it, the first clubs were created in which members shared the cost and usage of a car. The main motivation of these clubs was to gain the benefits of mobility without the cost of ownership (Shaheen et al., 1998). Greater mobility remains one of the advantages of car sharing, especially for people who do not own a car. Sharing the costs leads to the next advantage. The fixed costs of owning a car are converted into variable costs; you only pay when you need a car. The cost of insurance and upkeep are one of the most disliked features of car ownership (Millard-Ball et al., 2005). Also (unexpected) costs, such as maintenance and parking costs, are removed.

The effects of car sharing on car ownership has been researched in many studies. (Shaheen et al., 2012) provide an overview of studies indicating the impact on car ownership in North America. These studies show a range of 2.5 to 55% of the participants selling an owned vehicle and 7 to 70% of the participants avoiding a vehicle purchase. Not owning a car does not mean less mobility any more, but could improve mobility. The broad range of results for the different studies is caused by outliers. For example, the average of the 17 studies exploring participants selling their car is 25%, with 10 studies only deviating 1% from the average. This average cannot be used, as not all studies can be weighted equally. Not all sample sizes are known. It shows that the effects of car sharing depend heavily on implementation and location.

Car sharing services offer different types of vehicles, so users have the possibility to choose the type of vehicle that best suits the needs for their trip. For example, a small car will suffice to visit a friend, while a shopping trip might require a bigger car to fit the purchased goods.

Transportation infrastructure

In this thesis, the transportation infrastructure includes all means of transportation and infrastructure used to travel. With motorised mobility in cities estimated to double between 2015 and 2050 (OECD, 2017), the danger of overloaded roads within cities exists. This would decrease mobility within cities, as cars and buses are stuck in traffic more frequently. The influence of car sharing on reducing car ownership, could help weaken this growth. Another positive effect of car sharing that would contribute to better mobility, is an increase in cycling, walking and PT usage

(Millard-Ball et al., 2005; Martin and Shaheen, 2011b). This will be discussed more in-depth later in this chapter.

Less car ownership can lead to an increased parking availability, as less cars need to be parked. This could lead to a reduced need for parking spaces, decreasing the amount of parking spaces that need to be built in new development areas, allowing a different allocation for land. Cars also spend less time idle, decreasing the time spent stationary on a parking location. Some car sharing companies offer users of their service dedicated parking spaces, which users describe as an attractive feature (Millard-Ball et al., 2005). Parking privileges also increase car driving efficiency, as less time is wasted searching for a parking location.

A commonly mentioned advantage is a reduction of congestion. Decreasing car ownership, reduces the number of cars present on the road at the same time. Although mentioned in multiple studies, it has not been studied in a real-life scenario yet. Congestion decrease caused by car sharing is currently difficult to prove, as car sharing needs to be widely adopted before this effect can be noticed. Predictions can be based solely on estimated car ownership decrease, not measured car ownership decrease.

Environment

The positive impact of car sharing on the environment include less vehicle travel and lower emissions (Martin and Shaheen, 2011a; Shaheen and Chan, 2015). Less vehicle travel and the use of more fuel efficient or electric cars results in lower emissions.

Not only are cars used less often because of car sharing, the total amount of kilometres driven with cars, Vehicle Kilometres Travelled (VKT), is also lower. (Shaheen et al., 2012) provides an overview of change in average VKT in North America caused by car sharing. The VKT decrease ranges from 3 to 73%. As discussed in the advantage of the individual section, this wide range of results is caused by outliers. The average decline in VKT is 42%, with five of the 13 studies within a 5% deviation. Meijkamp (2000) showed in a study of four car sharing services in the Netherlands, the average yearly kilometres of car sharing users declined by 33% after becoming a member. Of the people who substituted their private car for car sharing, the decrease in VKT is even larger (65%). The frequency of trips does not decrease, but car travel is replaced by bike, train or bus use.

Participants in a Dutch car sharing research travelled an average of 1600 km less per year by car than they did before (Nijland et al., 2015). This results in an estimated 8 to 13% less CO_2 emissions. Estimations show, if 10% of the car users in the Netherlands would use car sharing (10 times more than currently) and they would also drive 1600 km less per year, this would result in a VKT reduction of maximally 1.3 billion km, a decrease in of the VKT in 2020 of 0.5 to 1% (Jorritsma and Mobiliteitsbeleid, 2015).

However, a decrease in VKT might not be directly achieved. (Cervero et al., 2002a) found members of a San Francisco based car sharing service actively using the service for nine months drove farther, longer, and logged more VKT than members driving private vehicles. They conclude that this specific car sharing service stimulates motorised travel. This could be caused by the fact that two-thirds of the members came from carless households.

New research was performed four years later at the same company to look at the long-term effects of car sharing. Now they found that the average VKT of members decreased compared to non-members (Cervero et al., 2006). The sale of private cars and abstaining from buying an additional car were found to explain this finding.

Also, the way car sharing is implemented, influences the VKT. Model simulations found that introducing car sharing only in inner London would have little influence on the VKT driven in cars (Le Vine et al., 2014). However, introducing the service across London would result in a decrease in VKT.

As is mentioned in the above discussed studies, it is important to keep in mind that participants of surveys who are asked to indicate their VKT before and after joining car sharing, need to make an estimation. Errors and biases can creep into their estimations. Another limitation is that the results only provide a snapshot, as the frequency, timing, and location of mobility of people is susceptible to change.

2.1.2 Disadvantages

To use a car sharing service, people need to have an account registered at a service. The registration process is an entry threshold. First time impulsive usage is not possible because all services need a copy of your driver's license in order to register.

It is unknown when car sharing is financially beneficial. Looking at the price per trip for car sharing gives a wrong impression of the cost of car sharing. Car owners usually only take fuel costs and not fixed costs into account when estimating the costs for their car trip. The car sharing price includes fixed and fuel costs. Therefore, a single car sharing journey seems more expensive. However, car sharing is cheaper than owning a car if the annually driven kilometres stay below a certain limit. This limit ranges between 10,000 and 16,000 kilometres (Litman, 2000; Shaheen and Cohen, 2007; Bert et al., 2016), depending on location and organisation. No definitive limit exists, which increases the uncertainty for people whether car sharing would be financially beneficial for them. There are too many external factors (car sharing costs, fuel costs, fixed costs of private car) to consider to provide one fitting answer for everybody.

For new or potential users, the availability of a car could also be a threshold. The possibility exists that no car is available close by. It is up to the car sharing company to minimise this risk and guarantee that each user can travel to their destination. If a service is not reliable, people could get stranded.

A large disadvantage of car sharing related research is the difference between what people answer in a survey and what they actually do. Research indicates a large potential for car sharing as described in the introduction of this section. The interest does not translate into actual users. This is a common phenomenon in behavioural change surveys (Wong and Sheth, 1985), but could also be the indication that car sharing services are missing a killer functionality for a larger public.

2.1.3 Types of car sharing

Following the discussion of the advantages and disadvantages of the general idea of car sharing, an overview is given of different models of car sharing.

1. Business-to-consumer (B2C)
   A company owns a fleet of vehicles which consumers can rent. This variant can be split into two categories.

   (a) Round trip car sharing
   The rental period is started and ended at the same location. (e.g. Greenwheels)

   (b) One-way car sharing
   A rented vehicle is picked up from a location and can be dropped off at another location within a designated operating area. (e.g. Car2go)

2. Peer-to-peer (P2P)
   The shared cars are owned by and rented to individuals. All P2P services use the round trip principle.

   (a) Business intermediary
   Private car owners list their car on a platform where other people can apply to rent it. (e.g. Snappcar)

   (b) Neighbourhood sharing
   A group of people buy a car together, allowing everybody to use the car when needed.

Research from CROW-KpVV (2016) shows that the recent growth of car sharing in the Netherlands can largely be contributed to P2P car sharing. P2P is easier to scale, as one of the problems of the B2C model is the large investment needed to expand a vehicle fleet and to keep the fleet up-to-date.

Knowledge about round trip car sharing might not be directly transferable to one-way car sharing (Becker et al., 2017). Round trip is found to complement PT, while one-way is more often used as an alternative to PT (Le Vine et al., 2014). One-way provides more freedom than PT and round trip. Furthermore, it does not pose limitations in terms of travelling back to the starting location. Le Vine et al. also found that the two B2C categories have different market potentials. One-way car sharing in London was found to have a three to four times larger number of potential subscribers than round trip car sharing.

Münzel et al. (2017) find that the car to inhabitant ratio for both B2C categories is not significantly different, even if their operating areas have different population densities. Their fleet sizes vary significantly, but for both categories operating in urban areas, the number of cars per 1000 people is about equal to 0.24.

Besides these differences, a distinction between parking locations can be made.

1. Station based
   The rental period can only be ended in a special parking space, created and reserved for cars owned by the car sharing company.

2. Free floating
   The rental period can be ended by parking the car in any parking space.

Round trip car sharing is mostly combined with station based parking locations, while one-way car sharing offers both types of parking options.

The most suitable markets for station-based round trip car sharing are dense urban areas with good PT coverage (Stillwater et al., 2009; Grasset and Morency, 2010). Station-based car sharing is heavily influenced by the type of PT that is available. Light rail, such as metros and trams has a positive effect on car sharing demand. On the other hand, regional rail has a negative effect on car sharing demand. It should be considered that Stillwater et al. note limitations of the available data, such as sample size and biases.

New members of a car sharing service are found to increase cycling, walking and PT usage (Katzev, 2003; Millard-Ball et al., 2005; Martin and Shaheen, 2011b). This could have several explanations. Firstly, it could be that car sharing users are more aware of the impact of driving a car and are for that reason more actively trying to minimise its usage. They are only a member of a car sharing service for the incidental need for the mobility offered by a car. Secondly, the cost per trip seems higher for car sharing than for a private car. Part of the otherwise fixed costs are included in the trip cost. The higher one-time cost could motivate people to use a different mobility type. Contrary to the above-mentioned studies, one of the outcomes of a free floating car sharing study shows that non-car owners who start using car sharing reduce their bike, walk and PT trips (Firnkorn, 2012). Both Martin and Shaheen, and Millard-Ball et al. do not indicate which type of car sharing service is researched, but both have a large sample size. Free floating might offer people more freedom in their mobility and as a result replace other mobility types. Other possible reasons for the different outcomes could be the novelty effect. The participants in the study performed by Firnkorn might be newer users than those of the other studies. Because of this novelty, they use the service more often, but their usage might decrease over time.

2.1.4 Users

In this section, the users of car sharing are analysed. First, the demographics found in literature is examined. Secondly, the motivation to use car sharing is described. Thirdly, the most used trip types are discussed. Lastly, liked and disliked feature are considered.

Demographics

Several researchers have tried to characterise the demographics of car sharing members. Car sharing users are found to be well-educated (Katzev, 2003; Burkhardt and Millard-Ball, 2006), live in below average size households (Millard-Ball et al., 2005) and live in medium to high density areas (Cervero et al., 2002b; Burkhardt and Millard-Ball, 2006).

However, no differentiating results are found regarding the income of car sharing users. Costain et al. (2012) found that car sharing is popular among low income, while Millard-Ball et al. (2005) found it to be popular among middle to high income groups. Given the cost reduction advantage of car sharing, low income groups could benefit the most. However, it would only be beneficial if their kilometres per year are below a certain limit, as discussed in the disadvantage section of car sharing.

Research indicates that a large part of car sharing users are relatively young (Burkhardt and Millard-Ball, 2006) and range between 25 and 40 years old (Millard-Ball et al., 2005; TNS Nipo, 2014; Kim et al., 2015). This might not be the actual or the only user group for car sharing as car sharing is still considered an early innovation. The characteristics described in this section show similarities to the demographics of early adopters (Hobrink, 2014; Kennedy and Funk, 2016). The demographics could change when car sharing becomes a more established service.

Motivation

As described in the car sharing advantage section of this chapter, car sharing removes the fixed costs of car ownership and can lead to financial savings when the annually driven kilometres of a member are below a certain limit. This advantage is also reflected in research, showing that financial benefit is recognised by car sharing members as a big motivation. Financial motives were found to be the primary reason of becoming a car sharing member in Austria (Steininger et al., 1996) and Leiden, the Netherlands (Meijkamp, 2000). Other studies found it to be a secondary motivation (Katzev, 2003), with the occasional need for a vehicle being the primary motivation.

Four motivational patterns found by Schaefers (2013) also indicate costs and convenience as important incentives to become a car sharing member. The third pattern, lifestyle, describes an affection for the recognisability of the cars. Other members can be recognised and create a feeling of a car sharing community. The fourth pattern is an environmental motivation, based on environmental awareness and the perceived sustainability of car sharing.

Other motivations are a perceived greater convenience or shorter trip time compared to PT (Meijkamp, 2000; Kim et al., 2017). This last motivation is most prominent for off-peak travel, when PT trip frequency declines (Costain et al., 2012).

Trips

Car sharing trips are different than the average private car trip. Owned cars are mostly used to commute, while car sharing use does not follow a pattern. Car sharing trips are more occasional trips and its usage pattern varies (Millard-Ball et al., 2005). Millard-Ball et al. found that the average number of trips of car sharing members per month is two. These trips are made when things need to be carried, a car is needed to get to the destination or multiple stops have to be made. Car sharing trips are short trips because of the way the price is calculated and that rental periods can only end in certain areas.

Research in the Netherlands found that the most common trip motivations are visiting family or friends (15%) and days trips/recreational activities (14%) (TNS Nipo, 2014). Other categories are not shown.

Car sharing research in Toronto, Canada, also found that trips are mostly social or recreational trips (Costain et al., 2012). They also found that car sharing is used for shopping. Car sharing is observed to have a higher frequency of usage during the weekends.

A study in Switzerland found social activities and shopping the main purpose of car sharing (Becker et al., 2017). An interesting difference was found between one-way and round trip car sharing. Round trip is significantly more popular than one-way for transporting goods and leisure activities. On the other hand, one-way is significantly more popular for visits and commute.

Features

Research focused on wanted features in a car sharing service has already been conducted. Recent research conducted in the Netherlands using a large-scale survey, found that people want a cheap and flexible free floating car sharing service, which includes reserved parking for car sharing users (Dieten, 2015). This study uses a random sample of the Dutch population, not current car sharing users.

Costain et al. (2012) found that accessibility is the most important feature. With accessibility, the distance between the start location of the user and the nearest car sharing parking lot is meant. However, even if a user lives in close proximity of a parking space, the availability is crucial (Kim et al., 2017). It is important that when someone wants to use a car, one is available for direct usage. This is even more important when car sharing is used for the last mile because that leaves less room for flexibility. A user could get stranded because no car is available or they have to wait for a very long time. This would decrease the (perceived) reliability of the car sharing service.

Although people acknowledge car sharing to be less expensive than owning a car, even describing it as one of the best features, the hourly and mileage costs are also ranked highly on the negative feature list (Millard-Ball et al., 2005).

2.1.5 Current situation

Car sharing is located in densely populated areas with limited parking spaces (Millard-Ball et al., 2005; Burkhardt and Millard-Ball, 2006; Shaheen and Cohen, 2007; Loose, 2010). This is also found in research into how specific car sharing companies are doing. These companies are based in big cities, such as Toronto (Costain et al., 2012), Amsterdam (Suiker and Elshout, 2013), San Francisco (SFMTA, 2017), and Bremen (Glotz-Richter, 2016). Glotz-Richter (2016) found that in Bremen, every shared car has taken 15 private cars of the road, resulting in a total of 3700 less private cars already. The government has actively been trying to help and promote car sharing by dedicating parking spaces to car sharing and making them stand out. Newly developed areas have to comply to new regulation regarding houses to parking spaces ratios and are incentivised to integrate car sharing into the infrastructure. This collaboration between different parties has helped car sharing grow in multiple cities and is required to make car sharing a success. As described in the previous section, the demographics of car sharing users currently shows a lot of similarities with the behaviour of early adopters. A partnership between private and public entities can help car sharing companies reach mainstream customers (Terrien et al., 2016).

More local governments are becoming interested in integrating car sharing into their current transportation infrastructure. For example, the municipality of Enschede wants to create a service that allows their employees to travel to and from work by car, while the car is used by other people during office hours (Tubantia, 2017). For car sharing companies these initiatives are a great way to increase their customer base.

2.1.6 Alternative services

In this section, alternative services for car sharing will be discussed.

Bike sharing

Another solution for the FMLM of a journey is the shared bike. These bikes can usually be found at train stations where people can rent them for a fixed amount of money for a certain amount of time. In the Netherlands, the biggest bike sharing initiative is owned by the Dutch Railways (NS). Their fleet consists of simple bikes in a recognisable colour scheme located near train stations. It has become such a success that supply cannot keep up with demand (Lieshout, 2016). A disadvantage is that you always need to return the bike to a station again, so it can only be used for round trips. Bike sharing is a competitor because it provides people with means of transport to increase the door-to-door mobility.

Taxi services

Traditional taxi services can be seen as competitors for car sharing. Taxis offer a door-to-door service, but require some time before getting to your start location and cannot compete with car sharing in terms of price.

Alternative services, such as Uber and Lyft, are more direct competitors. Their price is most of the time lower than a taxi service. These services are barely active in the Netherlands, so in the Netherlands they are not yet a car sharing competitor. However, on the global market and especially in the United States where Uber and Lyft are expanding rapidly, both companies are and will be car sharing competitors.

Musk (2016) wrote in his Tesla master plan update about the company's vision regarding the future of Tesla and the autonomous functionality of their cars. When autonomous driving is made legal and technologically possible, Tesla wants to allow car owners to tell their vehicle to turn into a taxi and earn money. The car becomes part of a fleet of vehicles who will pick people up and drop them off where they want. This implementation has a lot of similarities with car sharing and their possible future when autonomous driving is available. Autonomous vehicles in combination with car sharing will be discussed later in section 2.4.

Private lease

Vehicle leasing allows the leaseholder to use a car for a fixed period of time (at least one month) for an agreed upon amount of money. The lease company is still the owner of the car. Monthly terminable contracts for private lease cars can be seen as an alternative for car sharing. Companies, such as Helder and Dealerleasing take away the maintenance and reparation responsibilities for its users, comparable to car sharing. However, the fixed costs remain. The monthly terminable contracts also allow more freedom in switching between different car sizes.

Car rental

Car rental can be seen as the precursor of car sharing. A car is usually rented for one or more days instead of a few hours and the rental expenses excludes fuel costs. Both car rental and car sharing include an own risk policy, which can be brought down by paying an extra fee. The main difference is that rental cars need to be picked up at a service location and that paperwork needs to be signed. Most car rental companies require you to return the car to the pickup location or ask for an additional fee to return it someplace else. Car rental companies also need a deposit.

2.2 Public transportation

In the Oxford dictionary, public transportation (PT) is defined as: "Buses, trains, and other forms of transport that are available to the public, charge set fares, and run on fixed routes" (Dictionary, 2017). PT is not directly demand driven, because schedules are created in advance, to which the drivers have to stick. In the Netherlands, PT is usually subsidised by the government and thus has governmental involvement. The government is actively thinking about how to improve the current PT situation and has recently released their view of PT in 2040 (Rijksoverheid, 2016b). Providing mobility in areas of low demand, connecting economic core areas as well as increasing mobility, sustainability, and innovation are some of the presented core ideas. Car sharing is also named as one of the upcoming innovations related to the increase of digital applications within PT.

In this section, the advantages and disadvantages of PT are discussed. After that, PT users are described, followed by a discussion about travel satisfaction.

2.2.1 Advantages

Travellers with PT have few responsibilities and do not constantly need to pay attention. Since they are not driving, they have time to relax, rest and/or read. This reduces the stress of travelling and makes the time spent travelling feel like less of a waste. Social interaction in the form of talking to other people on a vehicle is also possible. The usage of bus lanes in cities or on highways during rush hour also increases the travel time efficiency.

PT has a lower emission of harmful gases into the atmosphere. Efficiency is increased, because more people travel in a single vehicle. PT companies are actively trying to become more environmentally friendly. Examples are the agreement, signed with all transport operators, that all new buses from 2025 onwards will be emission free (Rijksoverheid, 2016a) and the since January 2017 wind farm energy powered Dutch Railways (NS) trains (NS, 2017).

The cost of travel with PT is lower than the cost of travelling by car. Fuel costs are shared over a larger number of people and part of the costs is subsidised by the government. Although this is also acknowledged by car owners (Beiraõ and Cabral, 2007), it is not seen as a key factor to switch to PT. The disadvantages outweigh the advantages.

2.2.2 Disadvantages

Handing over the driver responsibilities also has disadvantages, as it can be perceived as a lack of control. This lack of control is not only available while driving, but also while planning a route or waiting for a ride. A user is dependent on the time his ride leaves, at what frequency, and where the journey starts and ends. PT does not provide a door-to-door service, so people first need to travel to a dedicated departure spot. A bus driver is not allowed to deviate from his route to stop at the front door of somebody's home. This reduces the personalisation and flexibility of travelling.

If a user needs to transfer within one journey to reach his destination, waiting times increase the total journey time. This feels like a waste of time, because no progress is made. Delays can cause missed transfers and increase the total journey time even more. This reliability issue is limiting the willingness to travel with multiple mobility types within one journey.

Other disadvantages are the lack of privacy, especially if it is crowded. Personal space can be limited if a lot of people are trying to get into the same vehicle. A vehicle can be so crowded that people need to stand during the journey. This, in combination with a lack of comfortable chairs, make a PT journey less comfortable. It is also difficult to travel with big or a lot of baggage or goods because of space constraints.

2.2.3 Users

Many people travel by PT every day. For some, it is their daily commute, while others use it to travel to a social activity. People use PT for a different reason and with a different mindset. A commuter might want a silent journey, so he can get some work done, while a tourist might want to chat with his fellow travellers. A commuter does not need to receive a lot of information, because he has the whole trip memorized. A tourist needs extra information, otherwise he might miss his stop. This large difference in motivation, frequency, and knowledge makes it impossible to create one PT system that would fit everybody's needs. Research needs to make a distinction between different types of passengers. Van Hagen (2009) found six types of passengers in his research for the Dutch Railways (NS) and created personas for each passenger category. These are used to educate their conductors to quickly spot with what type of person they are dealing with and what the best way to provide them information is.

2.2.4 Satisfaction

Besides the differences in individual travellers, also a difference exists between the desires of a PT provider and a PT user. A provider might measure success rate in the number of vehicles that leave and arrive on time. However, if a bus waits two minutes to catch the transfers of another bus who is slightly delayed, this would not count as a success, but would increase user satisfaction. There is a conflict between the late arrival of a bus at a station (supply-oriented) and the late arrival of a traveller at his final destination (demand-oriented) (Rietveld, 2005). Another example is that a provider looks at the mean interval between buses at a stop or the average frequency, while a user looks at the mean waiting time. Rietveld (2005) says that supply-oriented measurements underestimate problems because the average quality is taken. However, bad quality tends to coincide with busy periods, resulting in more people having a bad experience. Good quality tends to coincide with quiet periods, with less people having a good experience and thus not cancelling the bad experience out. Rietveld argues that providers should consider both supply- and demand-oriented quality measures to create a better indication of their overall quality. Parkan (2002) also found that the evaluation criteria that a PT company uses are different from the criteria that a user values highly. The performance measurement method Parkan created for their client, incorporating both the productivity and quality, helped them gain insights to improve their performance.

Although PT providers may not directly take user evaluation into account, several researchers have already been exploring this field. Both Chowdhury and Ceder (2013) and Redman et al. (2013) found that reliability is the most important PT aspect. It is crucial for users to know that they can finish the journey they started and that they will get to their destination within a reasonable time frame. Big delays are deal breakers and cause anxiety among travellers (Cheng, 2010). Other anxiety causing problems include crowding, inner journey transfer and finding the right platform. Crowded vehicles are a big problem and one that is difficult to solve because the demand for PT fluctuates a lot during the day. During the morning and afternoon demand peaks, while in between the demand is much lower. People who travel by car are also affected by these peaks, but sit in the comfort of their own car. To rival private car travel and become a better transportation system, PT needs to offer the same or an improved comfort and convenience (Brownell, 2013). The speed, comfort and crowded aspects were also found by Hart (2012), in addition to higher customer satisfaction amongst incidental and elderly (65+) travellers. These groups are often less time bound and have different travel motivations than the regular travellers.

Other research indicates that the average satisfaction of people who have used PT is higher than of people who do not use PT (Guiver, 2007; Harms, 2008). Both Guiver and Harms find that the more frequently one uses a particular means of transport, the more positive one's judgement. In Harms (2008), thirteen product features were defined (such as comfort, price, speed and flexibility) and people were asked about each feature whether it fits with the car, bike and PT when used for commute and leisure trips. For both trip types, the safety of PT is highly regarded in comparison to other defined characteristics. But in none of the categories does PT score higher than the car or bike. The only other category in which PT comes close to the car is in the low price category.

2.3 Private car

A private car user is seen as somebody whose daily travels are performed largely or in total by private car.

In this section advantages and disadvantages of private car ownership and usage are given. Followed by a description of its users. Finally, private cars are compared to PT.

2.3.1 Advantages

For an individual car user, direct benefits can be noticed. First of all, using your car for a single trip seems cheap. Costs are only made during a trip if a car needs to be refuelled. All other costs (except damage and maintenance costs) are fixed costs that are not considered when planning a car trip.

Secondly, a car gives its owner a sense of freedom and independence (Hiscock et al., 2002; Hagman, 2003; Guiver, 2007). Cars provide flexibility because they can be used when the owner requires it, without the need to check whether the car is available. They do not depend on other people, except, for example, when one car is shared between multiple people in one household. The road infrastructure has been designed around car usage, allowing car drivers to get practically everywhere. With a car, you can literally drive from door to door without getting out of your vehicle. The large number of roads and the car's travel speed, allow drivers to get to their destination fast.

Thirdly, a car provides privacy (Gardner and Abraham, 2007), personal space, comfort, and a sense of control over your environment (Guiver, 2007). You can leave stuff behind in your car and no one will judge your song preferences.

Lastly, with car ownership comes an attachment to the car and a social status. Buying a car is a big investment, so people carefully select which car they want to drive. Once the investment has been made, people become attached to their car or see it as a reward for their hard work (Hiscock et al., 2002; Beiraõ and Cabral, 2007).

2.3.2 Disadvantages

The disadvantages of private cars can be divided into individual and collective disadvantages. These two categories are not mutually exclusive.

One of the disadvantages for an individual user is the cost of car ownership. These costs can be divided into fixed costs (taxes and insurance), running costs (maintenance, fuel, and parking fees), and unexpected costs (fines and repairs). Over time, the monetary value of a car depreciates, which also needs to be considered.

Not only parking costs are a disadvantage, also the difficulty to find a place to park is. The unavailability of a parking space in close proximity of the final destination extends the journey time and induces stress. Other stress generators can be driving in general or driving in congested traffic during rush hour.

Congested traffic is a problem on both an individual and collective scale. The number of road vehicles in the Netherlands has been growing with 1.5% annually for the last two years (CBS, 2016a; CBS, 2017d), while annually driven kilometres with road vehicles also increased slightly (CBS, 2015; CBS, 2016b). In the first quarter of 2017, the total congestion increased by 3% compared to last year (ANWB, 2017). Worldwide the number of private cars is also increasing (OECD, 2017). Congestion leads to irritation and wasted time.

The advantages and disadvantages of private car ownership and usage are clear, but they do not all have the same weight when evaluated by users. Hagman (2003) found that personal and direct experiences form perceived advantages and disadvantages. However, information acquired via scientific research related to the negative effects on the environment is relativised. Therefore, Hagman (2003) proposes that researchers should focus on the way interviewees present their arguments, rather than their actual arguments.

The cost of ownership is a directly experienced disadvantage. However, travellers often exclude road tax, insurance and maintenance when asked about the travel expenses of using a private car (Gardner and Abraham, 2007). Participants in this study did not mention environmental issues regarding car use. They were more concerned with minimising journey time and effort, and personal space.

2.3.3 Users

Just like with PT users, different categories exist in which travellers can be placed. Jensen (1999) divides car drivers in three different groups: passionate car drivers, daily life car drivers, and leisure time car drivers. All the three groups like cars for the freedom and independence they offer.

Both Tertoolen et al. (1998) and Jensen (1999) find that car owners are aware of the environmental impact of car usage, but that they are unwilling to change. It is considered ineffective because the environmental impact when they stop driving is perceived to be small. Other people will continue to drive cars, which is considered unfair. They are only willing to change if everybody changes (Jensen, 1999). Higher taxes to discourage car ownership could result in car owners to believe that their payments give them a right to pollute (Tertoolen et al., 1998). Their research suggests that requesting individual drivers to reduce their car usage is not the best way to achieve less car usage. Cars give its users convenience, reliability, and a sense of prestige and mastery. These benefits need to be taken into account when policies are created to encourage people to lower their car travel or switch to a different mobility type (Hiscock et al., 2002; Ellaway et al., 2003). The societal norms would need to change to motivate large groups of people to reduce their car travel.

2.3.4 Private car versus public transportation

A lot of the differences between private car and PT travel can be traced back to independence. Private car users are not dependent on fixed travel times, locations and frequency, and other users. They can exert more control over their journey. This flexibility is one of the features that is missed in PT and creates a preference for private cars (Jensen, 1999). Research indicate that car drivers also enjoy driving a car and use it as a means of self-expression (Halko, 2012), which is not socially seen the same with PT. The time spend travelling with PT is considered a wasted time compared to the travel time with cars (Gardner and Abraham, 2007). This is counter intuitive, because when travelling with PT the user does not have to focus on driving. This permits him/her to do other things, such as work or read, while travelling.

2.4 Autonomous vehicles

The continuous advancement of technology result in more and more applications of artificial intelligence. One of these applications are autonomous vehicles (AVs). The increase in test pilots and talk about legislation indicate that self-driving vehicles could become the next big technological invention for motorised transportation. AVs could have a big impact on the way car sharing will work in the future. Therefore, AVs will be discussed.

First, the general advantages and disadvantages of autonomous vehicles are discussed. Then literature about the different levels of adoption of AVs and the time frame of these adoptions are considered. Next, the collaboration between AVs and car sharing is examined.

2.4.1 Advantages

The first advantage of self-driving cars is that people do no longer need to drive a car themselves. Some people experience driving a car as stressful and only drive because of the mobility. An AV would take away this stress, and potential stressful situations and allows its passengers to do something unrelated to driving. For example, people can play games, read or watch a movie, while commuters can work while travelling to not waste any productive time. This also means that it allows people to travel by car who could not before because of age or a physical disability. A larger group of people can experience the same mobility.

Also, the safety of driving will increase because driver errors can be eliminated and cars have a faster reaction time than humans. Cars are never sleepy, in a bad mood or drunk. It is estimated that human behaviour plays a part in more than 90% of road accidents in the United States (NHTSA and USDOT, 2015). Safety can also increase by communication and coordination between vehicles and infrastructure. AVs can warn each other about road conditions, and traffic jams, while intelligent infrastructure can calculate the optimal speed for vehicles to maximize throughput and improve traffic light efficiency. Vehicles can drive closer to each other, increasing the road capacity. The communication between cars prevents unexpected and unnecessary braking, which could otherwise result in traffic jams.

AVs need less parking spaces, because they can drop their passengers off and continue driving. Currently, it takes drivers in down town areas on average 8.1 minutes to find a parking space (Shoup, 2006). This results in wasted time, extra traffic, congestion and pollution. If the found parking space is not close to the destination, additional time is wasted by walking.

AVs also help reduce pollution by increased fuel efficiency as they can be programmed to drive more efficiently and drive closer together to benefit from each other's slipstream.

2.4.2 Disadvantages

Although AVs are expected to drive safer than humans, the technology still needs to prove itself to be totally safe. The cars that are driving around in the United States at the moment have a safe track record, but their current total mileage can statistically not be extrapolated to conclude that AVs are safer (Kalra and Paddock, 2016). Kalra and Paddock estimates that AVs would have to drive hundreds of millions of kilometres to confidently say that they are more reliable than a human driver. However, they note that the adoption of AVs does not only depend on the amount of testing, but mostly on the social acceptance.

This social acceptance also depends on the acquisition cost of an AV. The sensors and development costs that are required to create an AV, make it a more expensive alternative than a traditional vehicle. Also, the investments required to create a smart road infrastructure need to be funded.

The lowered threshold of usability for a wider audience, including people without a driver's license, induces more vehicle travel. The car will be used for more trips increasing the road congestion.

Other concerns about AVs are related to security and privacy. AVs should have a high level of security because it must not be possible to hack a vehicle and potentially let it crash. This means that AVs should have the possibility to be kept up-to-date, potentially over the air, and that AV manufacturers should regularly provide security updates for older vehicle models. These updates should pass rigorous testing because nothing is allowed to go wrong when a customer is driving in a vehicle. Worries about the privacy about AV drivers exists because AV cars have a lot more sensors and collect a lot of data. This data can be used to improve the algorithms and the intelligence of AVs, but also contains personal data from the travellers, such as pickup time and location as well as drop of time and location. If behavioural patterns fall into the wrong hands, criminals can know at what times people are at which location and pick the optimal time to rob their house.

Currently, AVs do not function correctly under all weather conditions. A low hanging sun (Yadron and Tynan, 2016), snow or rain can blind the cameras or decrease its accuracy. Reliability in all weather is important to support total vehicle autonomy.

Having AVs driving around on the streets could also influence other road users to behave less safe (Litman, 2014). For example, pedestrians might think that AVs will constantly monitor the environment and can anticipate every situation with fast reaction times. They will be less careful at cross walks, because they expect the cars to stop.

2.4.3 Level of adoption and time frame

Various research has been conducted to find the public opinion, potential and time frame of autonomous driving. Daziano et al. (2017) researched the willingness of people to buy autonomous functionality for their vehicle. They found that households would be willing to pay on average $3500 for partial automation and $4900 for full automation. It is important to note that these are averages, because one third of the respondents said they would not pay at all, while another third said they were willing to pay over $10,000. This indicates that the public opinion regarding AVs varies, especially if they need to pay extra to gain access to the functionality.

Recent research in the Netherlands found that more than half of the 1500 participants (55%) say that they want to be the driver in a car (Zelfsturing.it, 2017). One third of the respondents does want the AV functionality.

Instead of implementing autonomous possibilities directly into new vehicles, a different approach has been suggested. By iteratively increasing the autonomous functionality of cars, people will more slowly get used to it and experience its advantages. Examples of these autonomous functionalities are tracking lane boundaries, adaptive cruise control and collision warnings. Ford indicated in 2012 that they have the technology ready to support autonomous driving, but that they found that car drivers are not ready yet (Fitchard, 2012). People are uncomfortable with the idea of sitting in a car that drives autonomously, but are open to the idea of intelligent and environment aware vehicles. Brownell (2013) proposes to first create a communication network for cars to establish inter car communication and then move towards the cultural acceptance of fully autonomous cars.

The American National Highway Traffic Safety Administration(NHTSA) agrees with the incremental integration of autonomous functionality into new cars and describes four levels of AVs, with each higher level increasing autonomy and decreasing driver monitoring (NHTSA, 2013). The two highest levels of autonomy do not require a user that is actively engaged in driving activities. The NHTSA is currently investigating the best practises to implement autonomous functionality.

Several predictions are made regarding the time frame in which AVs would become accepted and integrated in the transportation system. This ranges from within a couple of years to the end of the century. Litman (2014) thinks that during the 2020s AVs are likely to be expensive novelties and estimates that it takes until 2060-2080 before the large benefits of AVs can be exploited. A large autonomous fleet is necessary to increase traffic density and reduce parking spots. The process is not expected to be limited by technology, but by the adoption and the slow fleet turnover. Modern vehicles are durable and low- and middle-income car drivers are more inclined to buy a cheaper or second-hand car. Within the same research Litman notes that other car technologies took a long term to be integrated into cars, although their advantages are obvious and their additional costs low. For example, air bags took 25 years to get mandated by U.S. federal regulation and automatic transmissions are after more than 50 years still not standard in cars.

Arbib and Seba (2017) are more optimistic and foresee a big future for AVs and expect that within 10 years 95% of all U.S. passenger miles will be travelled with an on-demand AV fleet owned by one or multiple businesses. They have identified 2021 as the year in which autonomous vehicles become widely available and will disrupt the existing transportation model.

2.4.4 Car sharing integration

When AVs are used in a car sharing fleet, the potential customer base of car sharing increases. AVs allow people without a driver's licence and people who cannot drive a car for other reasons, to travel by car without the use of a human driver. However, the biggest added value of AVs for car sharing is that it allows vehicles to be relocated without human involvement. The ability to travel without passengers allows better anticipation of changing vehicle supply and demand.

The system that can be created by combining car sharing and AVs resembles a taxi fleet. Users can request a vehicle to pick them up and drop them off at a specific location. It is no longer necessary to walk to a car, as car sharing transforms into a door-to-door service.

Two different adoption scenarios can be created when talking about collaboration between car sharing and autonomous vehicle technology: (1) AVs will speed up the adoption of car sharing, or (2) car sharing will speed up the adoption of AVs.

In the first scenario, car sharing adoption is in the same order of magnitude as it is at the moment. By using AVs in car sharing fleets more people can use the service and it makes car sharing a more attractive mobility alternative. The AVs add extra functionality that was first missing in car sharing to make it a success.

In the second scenario, the integration of AVs in car sharing lets more people experience AV technology. The lower threshold to use AVs and be exposed to its usage, accelerates the acceptance of AVs as a means of transportation.

Research about setting up an AV fleet in urban areas to replace current car journeys find that every AV could replace ten traditional cars (Fagnant et al., 2015; Forum, 2015; Bischoff and Maciejewski, 2016; Chen et al., 2016). This would reduce the number of cars needed in urban areas drastically and free up space for different utilisation. Full car autonomy is important for these systems to function the way they are assumed to work in these studies and form a new mode of transport. In Forum (2015) it was assumed that no high capacity PT was used, which resulted in an increase of 89% of travelled kilometres for vehicles.

Car sharing is not the only way to start implementation of AVs in the current transport system. UITP (2017) proposes to start with implementing AVs in PT, because it allows to start operating in a limited area. This study does not see autonomous cars as a substitute for PT, because it lacks the vehicle capacity especially in densely populated areas. Different initiatives in PT have already started, such as an autonomous bus made by Mercedes, which had a trial period near Amsterdam (Mercedes, 2016).

A study asked people their preference regarding completing the last mile of a train journey with an AV, which is one of the use cases of car sharing (Yap et al., 2016). They found no significant preference for either fully autonomous cars or the ability to drive the car yourself. This could indicate that AVs might not be a requirement to attract car sharing users.

2.5 Summary and discussion

In this section, a summary of the important points found in literature is given, followed by a discussion about the found candidate car sharing features.

2.5.1 Summary

Car sharing has various forms of implementation. Some companies own a fleet of vehicles (B2C), while others allow people to rent their vehicle to other people (P2P). Some B2C services differentiate themselves by providing dedicated parking spaces to end a rental period to their users. Within a rental period, two trip types can be distinguished. The rental period has to end where it was started or it can end at a different location. Both types were found to have different usage strengths and to be used for different trip types. The advantages of car sharing can be divided into three categories: the individual, the transportation infrastructure, and the environment. The advantages for the individual are most important for users, with the biggest advantage being the reduced fixed costs. Accessibility, reliability and parking availability were found to be deemed important satisfaction criteria. Overall, car sharing is mostly used for incidental and social trips.

The biggest advantage of PT is the ability to perform non-driving related activities while travelling. PT is also beneficial for the environment as fewer harmful gases are emitted and recent agreements obligate PT providers to become more environmentally friendly. The lower cost of PT compared to car ownership does not persuade car drivers to switch. The disadvantages of limited flexibility and a lack of control outweigh the benefits. However, the satisfaction of PT users is higher than non-users, indicating a negative image of PT of non-users.

Driving and owning a car is associated with freedom and independence, and offers flexibility. The cost of a car trip seems low and reduces the usage threshold. Fixed costs, such as insurance, are not considered, but do make car ownership more expensive. Parking is seen as a big disadvantage of driving a car, because finding a parking space takes time and induces stress. Most car drivers are aware of their environmental impact, but do not feel obliged to change their behaviour.

The expected benefits of AVs include higher road safety and less required parking spaces. Concerns exist about the actual safety, as well as security and privacy. Estimations of the expected time frame vary. If AVs could be used in a car sharing fleet, the customer base of car sharing can be expanded because a driver's license would no longer be a requirement.

2.5.2 Discussion

With the literature review of car sharing, PT and private car completed, the found candidate features of car sharing can be described. First, the candidate features found in car sharing literature will be discussed. Followed by exploring candidate features that can be inferred from PT and private car literature.

What kind of candidate car sharing features can be found in literature?

The biggest distinguishing feature between different car sharing services is implementation of either *round trips* or *one-way trips*. Both forms of car sharing were found to be used for different trip types and have different market potentials. One-way car sharing provides users with more flexibility, and was found to be a wanted feature.

The functionality of one-way car sharing in a P2P business model is not viable. If a car owner who leases out his car, cannot be guaranteed a time frame within which he receives back his car, he loses his own mobility. Manual repositioning to return the car is expensive. Offering a one-way trip service also means that it is more difficult to offer dedicated parking spaces to users. One-way can be used in combination with dedicated parking spaces, but this limits the location freedom of ending a rental period. For a free floating one-way service, it is impossible to provide parking everywhere.

Dedicated parking spaces help to expand the accessibility of car sharing. People know where to find the car because it is easier to recognise and always available at the same place. Dedicated parking spots ease the stress of drivers to find a place to park and reduces time spent looking for a place. The driver also does not need to get a parking ticket or find a cheap parking spot as this is included in the rental price. When parking spaces close to transport hubs are offered, transfer times decrease and the multimodality threshold is lowered. To be able to offer these types of parking spaces, *collaboration with public entities*, such as cities or municipalities, is required. This collaboration could be further extended into better integration of car sharing in PT or to be developed neighbourhoods. By lowering the parking spaces to house ratio, and offering car sharing parking spaces, people could be incentivised to not buy a second car.

Offering *different sizes and types of vehicles* allows people to choose the vehicle that best fits their current mobility needs. Other mobility types do not offer this flexibility.

Although not a directly implementable feature, *reliability* of car sharing was found to be very important. People should always be able to start or end their journey. Reliability could be provided by matching the fleet size to meet the demand, perform manual repositioning, or motivate people to end their rental periods in areas with high demand. By performing area specific analysis, the demand and the required number of cars can be estimated.

In literature, the *reduced cost* of car sharing compared to vehicle ownership was acknowledged as one of the best features of car sharing. However, the exact savings for users are unclear. No specific answer has yet been provided, concerning the maximum annually driven kilometres a car sharing user could drive and pay less compared to driving those same number of kilometres with an owned car. Giving (potential) users a clear, personalised insight into their prospective savings, could convince more people to use car sharing.

Combining car sharing and AVs to create an *autonomous fleet of vehicles* could transform the usage of car sharing. People no longer need to be able to drive to use the service, resulting in a larger customer base.

Next the candidate features inferred from PT and private car literature will be explored.

Which features found in other forms of people transportation can be applied to car sharing?

Flexibility is offered by car ownership, but not by PT. Car owners can start a journey any time they want, while PT users are restricted by the predetermined schedule. Car sharing can offer a flexibility equal to car ownership, if it allows users to rent a car with minimal to no reservation time. This allows for spontaneous or incidental trips.

One of the complaints towards PT is the lack of *personalisation*. The service is not tailored to individuals, but to larger generic user groups. Car sharing can offer users more personalisation in terms of trip information and updated routes when delays occur. For a higher-level personalisation, user groups or even individual users can be targeted and tailor car sharing to their needs. For example, giving them a discount during specific times or updating them with PT travel information during a trip if they plan to continue their travels with PT. By showing a user he can minimise his journey time and efforts, car sharing becomes extra attractive.

Comfort and *convenience* are two features that people miss in PT, but find in driving a private car. Car sharing cars should be kept clean and have comfortable chairs. Convenience can be achieved through an easy rental procedure. It should be communicated that car sharing can offer both these features.

Parking availability and *price* were found to be big disadvantages of travel by car. By offering parking as part of the car sharing service, less time is wasted and less stress experienced while looking for a parking space.

The found candidate features form a provisional list of features for car sharing services. In the next two chapters, two different information sources will be used, online reviews and a dataset, to confirm the found features and, if possible, expand the list.

Chapter 3

Online review analysis

The goal of this chapter is to analyse the experiences of Dutch car sharing users through online reviews. Different car sharing initiatives have been set up in the Netherlands. They have been active on the market for multiple years already. During these years, people have had many different experiences while using car sharing. Some of these experiences have been shared online and provide an insight into what people consider positive and negative attributes of car sharing. Customer opinion is interesting and valuable, but difficult to obtain. Surveys follow a (strict) format and usually try to gather information from a well-distributed sample. To post experiences online, people have taken initiative themselves because they think it is deemed necessary. Although this method also has its limitations, it is a money and time efficient way to gather experience based opinions. To make it relevant for this study, the found experiences will be analysed with an emphasis on user experience with features.

In this chapter, the analysis of online shared experiences of users of two different car sharing services (Greenwheels and Car2go) and one car sharing alternative (OV-fiets) is described. First the methodology, with its limitations is presented. Then the to be analysed data is discussed, followed by the results of the analysis. With the limitations in mind, conclusions are drawn and the candidate features are defined.

3.1 Methodology

With the increasing integration of internet and social media in everyday life, the interaction between companies and consumers has shifted to the online space. It is no longer necessary to visit or call a company to ask questions, complain, or give feedback. Social media has become a common way to have personal interaction with a company. Companies seem more directly approachable. Some companies even have their own forums where people can interact with experts and other users. Although these interactions are not classified as reviews, they contain a wealth of information about how a product or service is used and how a user rates it. The individual interactions do not cover all aspects of a service, as a professional review would, but zoom in on one or multiple aspects. These business-to-customer and customer-to-customer interactions are deemed useful for this study because they provide insight into customer experience that would otherwise be difficult to obtain. For the remainder of this thesis, the online interactions will be referred to as reviews and their authors as reviewers.

The methodology for the analysis is based on an adapted form of content analysis (Stemler, 2001). Stemler describes content analysis as *"a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit* *rules of coding"*. It is a useful methodology for examining trends and patterns in texts. Content analysis is more than counting the frequency of created categories. The created categories are used to spot differences and similarities between the different interactions. Because of the small sample size used for this analysis, the frequency count is not deemed scientifically sound.

No categories are created beforehand, but they emerge as the coder goes through the reviews. The categories are based on described features and the user experience. Special attention is paid to deal breakers, reasons for not using a service, and a breach of trust.

The outcomes of the analysis are used as a sanity check of the literature discussed in chapter 2. The found features and their valuation can be evaluated against literature.

3.1.1 Limitations

Although content analysis has its strengths, it is important to notice its limitations. Firstly, the analysis is limited by the available material, which may not be an accurate reflection of reality. If one person complains about a feature, it could be that other people actually appreciate that feature, but have not expressed their appreciation online.

Secondly, the impact of good and bad experience cannot be considered equal. Bad experiences and impressions are salient, formed more quickly and more difficult to change once established (Baumeister et al., 2001). The negativity bias, weighing a negative experience more heavily than positive, is affecting the type of experiences people share online. When people share an experience, they mostly talk about the negative part because it is more attention grabbing (Kanouse, 1984). This is important to consider when reading both positive and negative reviews.

Thirdly, the external validity of the analysis is weak. The analysis cannot be generalised to a wider population. The reviews are selected at random, but cannot be considered a random sample. Too little background information about the demographics of the sample is known and the sample size is too small.

Fourthly, the review analysis is based on the Dutch market and for that reason only Dutch reviews are used. The translation of review text to category translation could lead to a different interpretation. The categories are created in English because this thesis is also written in English.

3.2 Data

More than ten car sharing companies are currently active on the Dutch market, varying in size and approach. In chapter 1, PT integration was described as one of the car sharing opportunities. Of all the companies on the market, only Greenwheels and Mywheels have some sort of integration with PT. For Mywheels this integration only goes as far as the possibility to open a rented car with your OV-chipkaart, the Dutch standard PT travel card. Greenwheels also offers this functionality. Greenwheels is unique in that it has a partnership with the NS, the biggest Dutch railway company. Therefore, Greenwheels cars have a dedicated parking location close to a many train stations. Greenwheels is also integrated in the NS-business card service.

Mywheels was left out of the analysis, based on a lack of reviews. As a replacement Car2go was chosen. Car2go does not have any integration with PT, but it was selected because it is one of the most successful car sharing services in the Netherlands, with currently more than 300 electric cars in Amsterdam.

As the third company, a car sharing alternative was chosen, the OV-fiets. This NS initiative provides bikes for rental at train stations. The OV-fiets can be seen as a car sharing competitor because of the bike friendly infrastructure in the Netherlands, Thus, it can offer the same FMLM advantage a car could.

The data selected for this analysis consists of online reviews, forum posts, and social media posts. These were found by using the search engine Google. The search query consisted of the company name plus one or two keywords. For each company, the used keywords can be found in Appendix A. The analysed reviews and the created categories can also be found in this appendix. For each review additional information is noted, such as source, type of website, format, and primary audience. The perceived tone of the review is categorised in three categories: positive (green), neutral (orange), negative (red).

3.3 Results

In this section, the results of the analysis will be discussed. First, the two car sharing services are examined separately, followed by an evaluation with respect to each other. Then, the OV-fiets is analysed, followed by a comparison of car sharing and bike sharing.

3.3.1 Greenwheels

The most frequently occurring category at the Greenwheels analysis is the 'Only useful when close by' category. This category encompasses all notions of the dependence of distance between start location of the user and the car. The shorter the distance, the more useful the service is deemed to be. The people who write these comments in their reviews live close enough to use the service and as a result their review is influenced by the survivor bias. Survivor bias means that only people or things who passed a certain threshold or criteria are looked at, and other instances are ignored. In the car sharing case, this could lead to the idea that the cars are well distributed over a city or the Netherlands. The people who note that you should live close to a car sharing parking place to use the service, all live close to a parking space and because of that use the service.

Another commonly occurring category is the 'High cost' category. People from the sample indicate that they feel they pay a lot of money to use Greenwheels. For reviewer number 9, the high price together with the transition to smaller cars, persuaded them to buy a car and stop using Greenwheels. Other reviewers note the high price as a downside, but do not describe it as a reason to stop using the service.

3.3.2 Car2go

One of the selling points of Car2go in Amsterdam is the possibility to park anywhere without additional parking fees if you end the rental period. In addition, they also have special Car2go parking spaces. Especially in a big city where parking spaces are scarce and expensive, this sounds like an ideal solution. The reviewers indicate that they perceive this as a big advantage, but it does not always serve its purpose. People still have trouble finding a parking spot and sometimes they find a parking space dedicated to Car2go occupied with a non-Car2go vehicle. Although it is difficult for Car2go or any car sharing company, to prevent unauthorized vehicles from parking in their reserved parking spots, it is very frustrating for the affected user. Car2go indicated in an interview that they do not receive a lot of notifications about wrongly parked cars (Suiker and Elshout, 2013). Although an issue with wrongly parked cars was mentioned in a couple of reviews, it shows that the reviews are not a real representation of what happens to a lot of car sharing users. On the other hand, the classification 'not a lot' is very subjective and Car2go will not publicly state that a lot of their customers have problems with parking.

The choice of Car2go to offer its users only electric vehicles (EVs) creates an environmental friendly image. The current battery technology for EVs does have a downfall, their unreliable maximum distance. As two of the reviewers noted, the distance drops drastically if the outside temperature is low. The batteries drain quicker, resulting in more time spend charging and less time driving. Combustion engines do not have this seasonal dependency. It is important to educate people of this phenomenon beforehand, to prevent them from getting stuck somewhere with an empty battery.

3.3.3 Greenwheels vs Car2go

The main difference between the two services is the types of cars they use. Car2go uses Smart Fortwos, which are known to be small. One car can only transport two people at a time and does not have a lot of trunk space. Greenwheels car fleet consists of city cars, station wagons and small vans. All Greenwheels cars are bigger than Car2go's cars, but only the Greenwheels reviewers complain about small cars. People know Car2go uses smaller vehicles and have different expectations. Expectation management by a car sharing company is very important. People need to know what to expect, so they can anticipate the situation.

Although the sample size is small, it is worth noting that the reviews give no indication of the car sharing advantages described in the literature. The Car2go reviews do not even speak of the EVs environmental advantages. Only one Greenwheels reviewer (review 10) notes that car sharing is an environmentally friendly alternative, but she focuses mostly on the fuel efficiency of the car. This efficiency is not limited to a car sharing service.

3.3.4 OV-fiets

Although the OV-fiets can be seen as an alternative to car sharing, car sharing is not mentioned in one of the analysed reviews. The users of both services seem to have different mindsets when it comes to mobility. This could be because of the limited sample size.

However, the OV-fiets is seen as alternative for the bus. Not only to destinations where no bus connection is available, but also on lines where the bus is crowded.

The OV-fiets is seen as an extension of a train journey, but not of a bus journey. This could have two explanations. Firstly, the bikes are located near train stations and not near bus stops (except when the bus stop is located at a train station). Therefore, people can only start their OV-fiets journey at a train station and bus stops located near a train station. Secondly, bus lines have a lot more branches and stops, resulting in a higher network density. The distance people need to travel from a bus stop to their destination is likely shorter than from a train stop to their destination.

The reviews from the forum of the NS (reviews 1-7) indicate that users come across a different procedure to rent a bike at different stations. It is understandable that not every place can be equipped in the same way, but the reviewers even talk about a different order of the steps needed to complete a rental. The lack of a standard procedure implemented at all rental stations creates confusion for its users and has a negative influence on the user experience. This only affects people who use bikes at different stations, but is unnoticeable for people who only use the OV-fiets from one certain station. Establishing a standard procedure would create a better experience for people renting from different stations and for a better possibility to evaluate the overall service quality of the OV-fiets.

An emerging theme in a lot of the reviews is the current state of the bike. The reviewers do not seem to mind that the bikes are not new and do not have a lot of luxury. They can even look past a broken light. However, a broken bike, which cannot be used, does result in a very negative experience. A broken bike decreases the reliability of the service. Reliability is very important for a transportation service, because people do not like the uncertainty and do not want to get stranded. There seems to be some leeway in terms of maintenance condition, if the core functionality (riding a bike) still works. Some bike depots close before it gets dark, which motivates people to return the bike earlier and decreases the need for bike lights. In the Netherlands, bike lights only need to be present on a bike when it is dark or when weather conditions create bad visibility (Rijksoverheid, 2017).

3.3.5 Car sharing vs bike sharing

The main similarity found in the reviews seems to be that both car sharing and bike sharing are used to get to places where no PT is available. Bike sharing is also used in combination with PT, more specifically the train.

A difference is that the OV-fiets is more difficult to use as the first mile of a journey than car sharing. Car sharing can be distributed over a larger area, while OV-fiets locations are concentrated near train stations. So, if you do not live near a train station, you cannot use the shared bike for the start of your journey. If the final destination of your shared bike journey is not at a train station, you still need to return the bike. Car sharing does not have this difficulty, if you use a free floating service.

What does make car sharing more difficult is the unpredictability of where a vehicle is available. The bike starting point is always the same. However, for a car sharing service without fixed parking spots, the location of each car can change every day.

As mentioned in the OV-fiets reviews, one person (review 4) is willing to pay to be able to make a reservation for a bike. This is a common feature in car sharing and gives users the guarantee that a car is available when they need it. A Greenwheels reviewer (10) describes this process as simple.

In the OV-fiets reviews, multiple remarks were made about the state of the bikes and that some of the bikes required maintenance. For a car sharing service this would be unacceptable. For example, a broken light on a car is very dangerous and would result in a fine. The failure of other equipment inside a car is also not acceptable.

The standardisation issue of the OV-fiets should not be a problem for car sharing. No special facilities need to be designed where people come to rent a car. When reservations can be made via an application on a mobile phone, everything can be done in software. What needs to be standardised is the placement of the hardware inside the car and the procedure to start and end a rental period.

3.4 Conclusion

This chapter looked at the different experiences people shared online. Most reviews were as expected and expressed in the limitations section negatively biased. This is important to keep in mind, because it helps to put these reviews into perspective. The positive reviews were underrepresented, but their presence indicate that car sharing does not only produce negative experiences.

The question related to this chapter is:
What are the experiences of car sharing users with car sharing and its current features?

The ability to draw valid conclusions is limited because of the limited sample size and the distribution of the sample. However, some aspects found in literature were also found in the analysis. The cost of usage is a barrier because it seems higher than the single usage of a private car. Giving people more insight into the cost of usage compared to private cars could help them put it into perspective.

Of the advantages of car sharing found in literature, the reduced fixed costs and environmentally friendly effect have been mentioned, both in only one review. Whether this is because of a negativity bias or not feeling the need to mention the advantages, is unclear. The limited sample size could also give a skewed perspective.

It was found that not only the type of features that a car sharing service provides are important, but also whether they are communicated to (potential) users. The fact that Greenwheels and not Car2go customers complained about small cars, while Greenwheels offers bigger cars than Car2go, shows that user expectation management is crucial to prevent bad user experiences. The same holds for the electric cars of Car2go, which need explanation about how to charge, as well as its limited range in cold weather.

None of the Greenwheels reviews mentioned anything about the collaboration between the NS and Greenwheels. The ability to open a car with the standard PT card was mentioned as a nice feature, but that feature is not limited to the collaboration of Greenwheels with the NS. There was no indication that the cars were used for FMLM mobility.

Although rural areas and the usage of car sharing together with PT were not found in the reviews, the conclusion cannot be drawn that rural areas do not have potential, or that trips combining car sharing and PT do not happen at all. The sample of the online reviews is too limited to draw that conclusion. A larger sample is required. Therefore, in the next chapter, a large dataset with the daily mobility of people in the Netherlands is analysed to find FMLM behaviour.

Chapter 4

Data analysis

The goal of this chapter is to investigate the rural area opportunities and integration of car sharing in PT. A dataset, containing the daily mobility in the Netherlands, is analysed by comparing urban and rural area trips, and examining multimodal trips.

First, the dataset, its usage, and its limitations are presented. Secondly, a preliminary data analysis is conducted to understand the data and how it can be used. Thirdly, the data analysis questions and approach is presented. Fourthly, data research is conducted to answer the data analysis questions. Finally, the data analysis questions are answered and candidate car sharing features are deduced.

4.1 Data

In this section, background information about the to be analysed dataset is presented and its usage is described. Next, the limitations of the data and conclusions are discussed, followed by a preliminary analysis to get acquainted with the data and establish research questions for the analysis.

4.1.1 Onderzoek Verplaatsingen in Nederland (OViN)

Since 2010, the Dutch bureau for statistics (CBS) conducts a yearly, nationwide study called OViN (Onderzoek Verplaatsingen in Nederland, (CBS, 2016d)). The goal of the study is to obtain information about the daily mobility of the Dutch population. Each participant is asked to provide their travel movement of one specific day. Within this research, the mobility behaviour is described in terms of place of origin and destination, time of travel, means of transport, and motive for travel. In addition, attention is paid to the background variables for a particular movement pattern and choice of transport. Participants are also asked to give more personal information to obtain a better view of daily mobility in relation to demographic. The most recent available study is used, which dates from 2015. The 2016 study can be expected around July 2017.

Participants are asked in a letter to fill in an online questionnaire. If filling in the questionnaire online is not possible, the survey can also be performed via a phone call or a researcher can visit the respondent at home. In 2015, 37,350 responses were collected on a total of 66,987 approached people. This means 0.2% of the total population participated. The participants of the study include everybody, except people who live in a care home or institution.

Since this research contains a sample from the total population, the results from the data analysis are not equal to the actual values, and thus have a margin of error. When the sample and the response of the basic research are insufficient to make reliable statements on a lower level of aggregation, additional work is done called 'meerwerk'. The basic research can be used to make statements about the travel behaviour in the Netherlands, but with this additional research travel behaviour in a particular region can also be described. 'Meerwerk' is done by obtaining more participants, who receive the same survey as the other participants.

Important conclusions from the 2015 research include a decline in travellers' kilometres, which can be traced back to a decrease in recreational travel. Less people have used a car as their transportation mode, but the total kilometres travelled by car remains the same.

4.1.2 Usage of the data

The data is used to analyse the overall movement behaviour in the Netherlands. By analysing the data in different ways, a better understanding is created of the daily movements that are performed. Rural areas are compared to urban areas based on different criteria that will be discussed later, and multimodality trips with PT are investigated. By analysing the findings, estimations can be made about the potential of both opportunities and whether car sharing fits within current mobility patterns or if people need to change to incorporate car sharing into their mobility patterns.

4.1.3 Limitations

The first limitation originates from the dataset. Although the sample size is large and seems to have a well distributed demographic, caution needs to be taken when drawing conclusions. It also needs to be considered, that it only contains data from the Netherlands.

Secondly, the dataset contains a classification created by the CBS (CBS, 2017a) for every municipality on a scale from one to five ranging from not urban (less than 500 addresses per km^2) to 'very strong urban' (more than 2500 addresses per km^2). Within the dataset, the average value for a municipality is given to an address, instead of the value for a specific address. This reduces the accuracy to determine the population density of an address.

Lastly, it is unclear how accurate the distances in the dataset are. Participants are asked to estimate their travel distance. Unrealistic speeds are filtered out and recalculated based on other given variables. However, less obvious mistakes might not be corrected. The distance category length distribution is also unclear, because the steps are not equal.

4.1.4 Preliminary analysis

The dataset consists of around 115,000 entries filling 166 columns, each with abbreviations of the data that they contain. It is difficult to understand the contents of the data just by looking at the tables. Therefore, a preliminary analysis is conducted to understand the way the data is organised and how it can be used. The insights gained during this analysis, are used in the deeper data analysis.

Motivation and means of transportation

To start, an overview has been created (see Table 4.1) to see the distribution of main means of transport used for all data records. The majority of the travel is performed by car (44%), but with 26% bikes are a close second. PT has a mobility share of 11% (Train and Bus/tram/metro).

	Whole week	Work week	Weekend
Car (driver)	30	30	29
Car (passenger)	14	11	23
Train	6	7	3
Bus/tram/metro	5	6	4
Moped/scooter	1	1	1
Bike	26	27	21
Walk	16	16	18
Remaining	2	2	1

TABLE 4.1: Means of transport used during the whole week, work week and weekend in % (OViN 2015)

	Whole week	Work week	Weekend
To/from work	18	21	6
Business visit	2	2	0
Services/Personal care	3	4	1
Shopping/Groceries	20	19	24
Education	12	16	1
Social visit	13	10	24
Social recreation	18	15	29
Tours/hiking	6	5	9
Different	8	8	6

TABLE 4.2: Trip motivation during the whole week, work week and weekend in % (OViN 2015)

Each participant is asked to indicate his/her motivation for a journey, which is visualised in Table 4.2. The different motivations can be divided into a time dependent and independent group. When travelling to school or to/for work, you are expected to be present at a predetermined time. The arrival time is fixed, not flexible. On the other hand, shopping, groceries, hiking, and social activities have no or a less strict arrival time. A flexible arrival time allows a flexible departure time. For example, somebody who is going shopping would not mind waiting 15 minutes for a vehicle to become available, while somebody who is going to a business meeting cannot afford additional travel time, and need to have a vehicle available directly. The means of transport for both groups is checked to search for difference between these trip motivations.

In Table 4.3 the motivation for movements with a flexible arrival time are broken down into different mobility modes. Compared to the results from Table 4.1, a decrease of 4% for PT can be noticed, as well as a 5% increase in walking. Although there is a decrease in car drivers by 4%, the percentage of car passengers increases by 4%. Thus, the ratio car drivers to car passengers changes. The flexible arrival time group contains more social mobility motivations, which could explain why more people travel together in one car. People go to or perform social activities together with somebody else.

In Table 4.3 the motivation for movements with a non-flexible arrival time are broken down into different mobility modes. These motivations have a lot less car passengers than the flexible deemed motivations (10%), while the car drivers increase by 6% (2% when compared to Table 4.1). Although cycling remains about the

	Type of motivation	
	Flexible[a]	Non-flexible[b]
Car (driver)	26	32
Car (passenger)	18	8
Train	3	12
Bus/tram/metro	4	9
Moped/scooter	1	1
Bike	26	27
Walk	21	9
Remaining	1	2

[a] 'Shopping/Groceries', 'Social visit', 'Social recreation' and 'Tours/Hiking'
[b] 'To/from work', 'Business trips', 'Services/Personal care' and 'Education'

TABLE 4.3: Means of transport for time flexible and non-time-flexible motivational categories in % (OViN 2015)

	Type of motivation	
	Flexible[a]	Shopping/Groceries
Car (driver)	26	32
Car (passenger)	18	14
Train	3	1
Bus/tram/metro	4	3
Moped/scooter	1	1
Bike	26	29
Walk	21	19
Remaining	1	1

[a] 'Shopping/Groceries', 'Social visit', 'Social recreation' and 'Tours/Hiking'

TABLE 4.4: Means of transport for time flexible motivations, with 'Shopping/Groceries', which is part of time flexible motivations, singled out in % (OViN 2015)

same, the amount of walking decreases by 12%.

To further look at flexible trips, the category 'Shopping/Groceries' was chosen for analysis. The means of transportation for the flexible motivations are repeated and compared to 'Shopping/Groceries' trips in Table 4.4. The 'Shopping/Groceries' category was chosen for further analysis because car sharing provides an extra advantage for these types of trips. A car has storage space for transporting more or larger items, which could not as easily be brought along on a bike or in PT. This is reflected in 6% more car driver trips and 3% less PT trips. However, the number of bike trips increases (3%). A decrease in PT usage, but an increase in bike trips can be seen in comparison with the means of transportation of all categories (Table 4.1).

The motivation for trips are important to consider when setting up a car sharing service because the mobility motivation might require a different type of vehicle. Social activities increase the amount of people that share one car.

Weekend versus week

In Table 4.2, an overview is given of the different motivations to travel during the weekend. During the weekend, the number of social trips (time flexibility) is significantly higher than during the week, while work related trips are very low. The motivation for trips during the week displayed in Table 4.2 show a decrease in social trips and a large increase in work and education related trips, as would be expected. The shopping category is also smaller (5%) during the week. As described in the user section of chapter 2, car sharing has a higher usage during the weekends. This can be explained by a higher motivation for social trips for which car sharing is used a lot. People are more flexible during the weekend. Car sharing can provide them mobility which they otherwise would not have had.

The types of mobility used during the week and weekend (Table 4.1) show a big increase of car passengers during the weekend (12%), while the car driver share remains about the same. So, during the weekend the number of people per car is higher than during the week, which could be explained by the increase in social activities. The usage of PT decreases during the weekends (6%) as well as the usage of bikes (6%).

Trip distance

The graph in Figure 4.1 shows the division of distance categories of different means of transportation. The peak for bike usage in the 1.0 to 2.5 kilometres category is significant. Train usage is minimal for distances below 10 kilometres, but spikes for distances over 50 kilometres. The car passenger peaks follow the same pattern as the car driver peaks. This is interesting, considering the survey targets individual people and not households.

If car sharing to aim for integration with PT, it should not become a competitor. For example, if car sharing is used for longer trips (<30km), it would compete with a large portion of the Bus/Tram/Metro usage as well as Train usage. So, users need to somehow be encouraged to use car sharing for shorter distances and switch to the train for longer distances.

The distribution of means of transportation for different distances can be seen in Figure 4.2 and Figure 4.3. On the x-axis, the trip distance increases. The first bar includes all trips longer than 0.1 kilometres, the second bar includes all trips longer than 0.5 kilometres, and so on. In Figure 4.2 the y-axis shows the number of trip and in Figure 4.3 the y-axis shows the percentage of trips from 0 to 100%. From 3.7 kilometres and further, the share of car travel experiences little fluctuation. Car drivers and passengers combined perform more than 50% of all trips longer than 1 kilometre. The amount of train travel increases as cycling and walking decrease. Until about 20 kilometres, the bus/tram/metro share remains stable, indicating they are mostly used for relatively short distances.

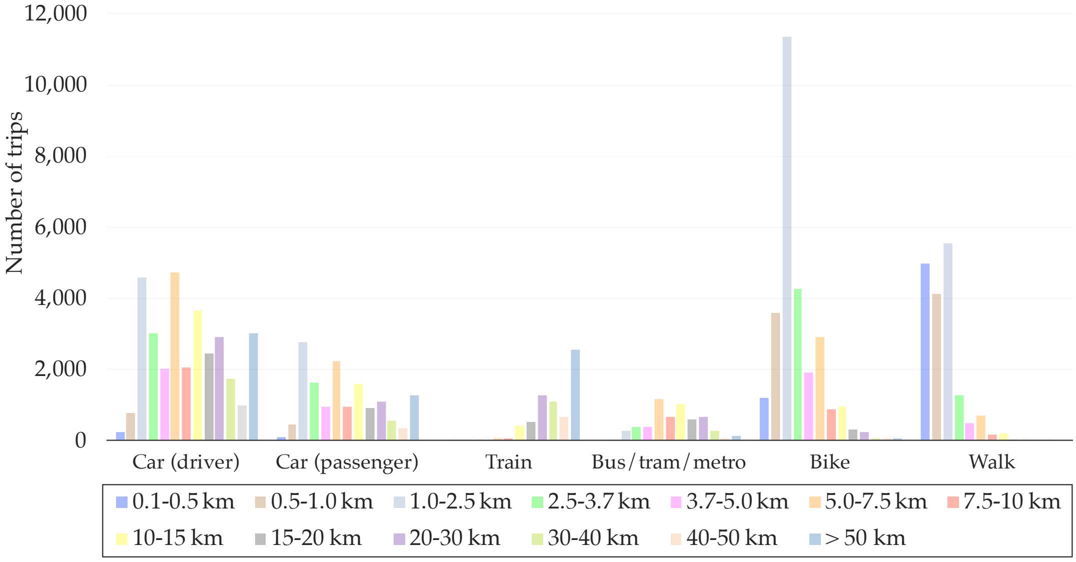

FIGURE 4.1: Overview of the number of trips per distance categories per mobility type (OViN 2015)

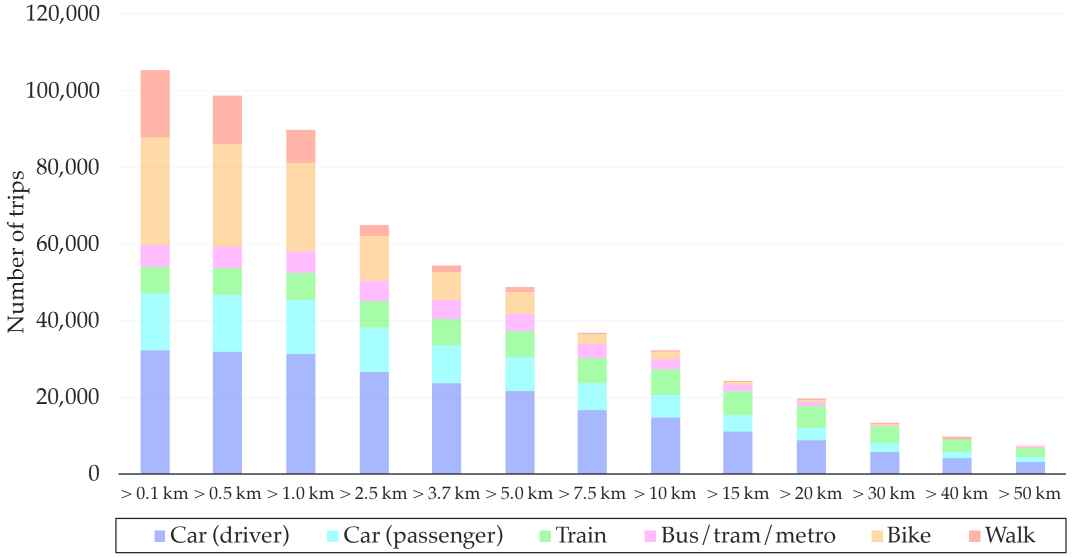

FIGURE 4.2: Number of trips versus increasing trip distance (OViN 2015)

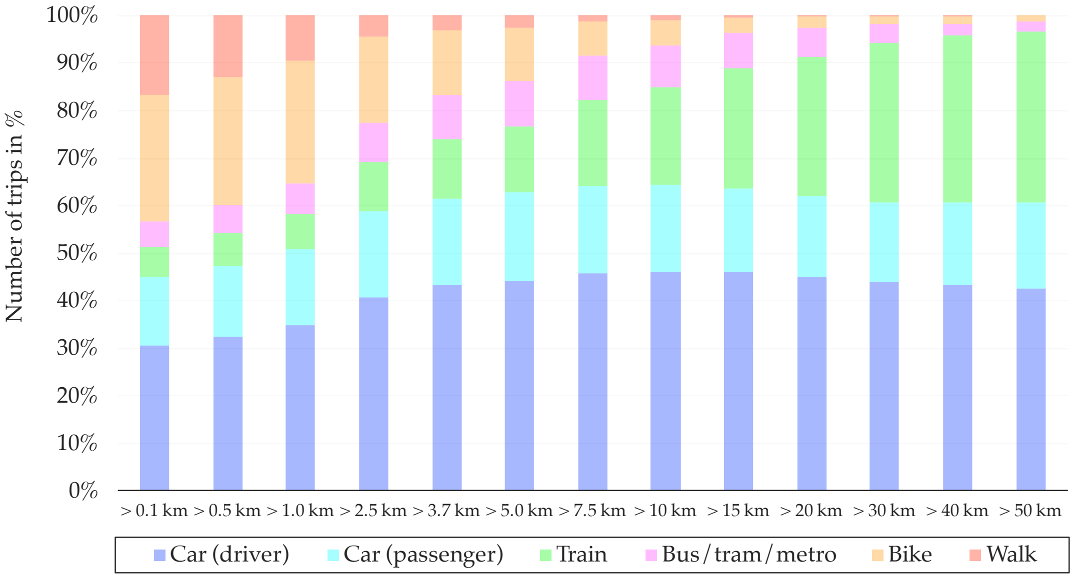

FIGURE 4.3: Percentage of cumulative number of trips versus increasing trip distance, same data as Figure 4.2, but in percentages (OViN 2015)

4.2 Data analysis questions

In chapter 1, expanding car sharing services into rural areas, as well as integrating car sharing into PT for FMLM usage were identified as opportunities for car sharing. These opportunities will be analysed in the dataset. Questions are created to guide the process. These questions will be introduced and the approach to answering them will be elaborated on.

Question 1: Urban versus rural

What are the differences and similarities between urban and rural travel patterns?

Car sharing companies are currently mostly active in urban areas, but the Netherlands also has a relatively large rural area and population. To estimate whether car sharing could also be applied in rural areas, the travel patterns are compared. A lot of similarities could show a car sharing potential for rural areas. Conclusions need to be drawn carefully because the average of the travel patterns of two group is taken. Outliers in either group could shift the results.

To be able to answer this question, the definition of urban and rural areas first needs to be defined. According to the definitions of the CBS, urban areas have a density of more than 1500 addresses per km^2 (CBS, 2017b), while rural areas have a density of less than 1000 addresses per km^2 (CBS, 2017c). The OViN dataset contains a separate column for population density for the place of residence of each participant. The density is divided into five categories: (1) less than 500 addresses per km^2, (2) between 500 to 1000 addresses per km^2, (3) between 1000 and 1500 addresses per km^2, (4) between 1500 and 2500 addresses per km^2, and (5) more than 2500 addresses per km^2.

The travel patterns are dissected into distance, time, speed, motivation, and means of transport. For both areas, the demographic composition is analysed in terms of age, occupation, PT usage frequency, and car ownership.

Question 2: First mile, last mile in PT

What are characteristics of the first and last mile of a PT trip?

In the introduction of this thesis, a lack of integration with PT was described as a weak point of the current car sharing set up. The dataset is used to analyse the behaviour of people who perform a multimodal trip, which can give more insight into the way people travel with PT. When a PT journey is performed with different modes of transportation, the term multimodality is applicable. It means that multiple modes of transportation are used within the same journey. To complete the first or last mile of a PT journey, people often needs to travel to or from a transportation hub. Especially interesting is the way which people arrive at a train station or bus stop and how they continue their journey from a train station or bus stop. These first mile, last mile trips are studied in terms of means of transportation, motivation, distance, and transfer, waiting and trip times. Also, the demographic composition is analysed in terms of age, occupation, PT usage frequency, and car ownership.

	Distribution (%)		Trip distance (km)		Trip time (min)		Trip speed (km/h)	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Car (driver)	26	36	18.8	18.5	25	23	42.6	47.5
Car (passenger)	13	15	17.3	17.7	25	23	40.9	44.5
Train	8	4	49.3	57.3	80	87	36.8	39.4
Bus/tram/metro	8	2	11.6	23.5	44	54	15.7	26.0
Moped/scooter	1	1	5.6	8.7	19	22	17.4	23.2
Bike	25	26	3.3	3.8	17	18	11.3	12.5
Walk	18	14	1.4	1.7	18	21	4.5	4.6
Remaining	1	2	21.8	25.6	41	42	31.6	36.4

TABLE 4.5: Trip distribution, distance, time and speed per means of transport in urban and rural areas (OViN 2015)

4.3 Results

Question 1: Urban versus rural

To compare urban and rural areas, the usage of different means of transportation is looked at. The area between urban and rural will not be discussed separately in this part of the analysis because it was found to be very similar to the results found in the rural areas. In Table 4.5 the distribution of used mobility types as well as the average trip distance, time, and speed are shown. In this table can be seen that in rural areas an extra 10% of the trips are performed by driving a car. The number of trips as a car passenger does not grow as much, which could mean that in rural areas the number of people per car is lower than in urban areas. The growth in car driver trips in rural areas (10%) is equivalent to the decline in PT trips. The train is used for 6% less trips, while the bus, tram, and metro are used for 4% less trips.

Although the bus, tram, and metro are used less, their average trip distance is more than double the distance in rural areas. This is to be expected, since services in rural areas are located farther apart. It could be that the distance of urban bus trips is close to distance of rural bus trips, but that the tram and metro usage decreases the average trip distance. In the Netherlands, trams, and metros are only located in cities, not in villages, so people in rural areas will, when starting their journey, only have access to buses and not to trams and metros.

Car trips do not show the same differences in distance as the bus, tram, and metro trips do. The car trip distance is about equal for both areas. Not only for the car drivers, but also for the car passengers. The time it takes for car drivers and passengers in both urban and rural areas to reach their destination is about the same. 'Bus/tram/metro' users in rural areas take 10 minutes longer to complete their journey, while travelling on average 12 kilometres more than users in urban areas. This means that the average trip speed is higher in rural areas. Possible explanations for this could be (1) more intercity bus connections which travel via the highway or provincial roads, (2) less stops or more distance between stops resulting in less time spend stationary, (3) less people travelling with bus/tram/metro resulting in less time needed to wait until everybody has left or gotten into the vehicle, and (4) less congestion and/or traffic lights.

The average travel speed is higher in rural areas for every transportation type, except walking which is the same. The average speed is only a couple of kilometres per hour faster, with only bus, tram, and metro as well as moped/scooter significantly faster in rural areas.

	Distribution (%)		Trip distance (km)		Trip time (min)		Trip speed (km/h)	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
To/from work	19	17	20. 1	22.1	35	29	34.4	45.6
Business visit	2	2	26.9	25.5	31	27	52.2	56.6
Services/Personal care	4	4	9.2	11.9	23	21	24.0	34.3
Shopping/Groceries	21	19	4.7	6.7	15	15	18.8	26.8
Education	12	13	10.1	13.2	27	30	22.4	26.4
Social visit	12	13	20.9	15.9	32	22	39.2	43.4
Social recreation	18	18	13.4	12.8	30	25	26.7	30.8
Tours/hiking	5	6	8.2	7.1	44	47	11.2	9.1
Different	7	8	13.1	12.8	22	18	35.7	42.5

TABLE 4.6: Trip distribution, distance, time and speed per trip motivation in urban and rural areas (OViN 2015)

Next, the differences between trip motivations are looked at. Table 4.6 gives an overview of the different categories, their distribution, trip distance, and trip duration.

As opposed to the trip means of transportation, there is no significant difference between urban and rural in distribution of trip motivation. The biggest difference is 2% for 'To/from work' and 'Shopping/Groceries'. For both categories, the trip distance for rural inhabitants is about 2 kilometres longer. However, the trip duration is six minutes shorter for 'To/from work' and equal for 'Shopping/Groceries'. This again shows that the average trip speed is higher in rural areas. This holds for all categories, except 'Tours/Hiking'.

Trips to go (grocery) shopping have the shortest distance and travel time for both rural and urban areas, but (after 'Tours/hiking') also have the lowest average speed. Table 4.3 shows that shopping trips are mostly performed by car (46%) followed by bike (29%) and walking (19%). Although the car is used for a large portion of the trips, the short trip distance has the most influence on the trip speed.

The social visit distance for urban trips is five kilometres longer than for rural trips. The higher people density in urban areas does not translate into friends and family living close together. Longer trips are needed to visit these groups of people.

There is no significant difference between urban and rural areas in terms of the trip motivation distribution. Differences do exist in trip distance and duration, but neither area has significantly longer trips. Rural areas have a higher travel speed in most categories, but do not have significantly shorter trips than urban areas. The urban area will be further specified to search for differences.

	Urban >250k	Urban >150k	Urban >100k	Urban	Rural
To/from work	20	19	19	19	17
Business visit	2	2	2	2	2
Services/Personal care	4	3	3	4	3
Shopping/Groceries	20	21	21	21	18
Education	12	12	12	12	13
Social visit	12	12	12	12	13
Social recreation	19	19	18	18	18
Tours/hiking	4	5	5	5	6
Different	7	8	8	7	8

e.g. 'Urban >250k' shows the distribution of trip motivation for people in an urban area in a city with more than 250,000 inhabitants.

TABLE 4.7: Trip motivation per urbanisation level and city size in % (OViN 2015)

	Urban >250k	Urban >150k	Urban >100k	Urban	Rural
Car (driver)	18	23	24	26	36
Car (passenger)	10	12	12	13	15
Train	9	9	9	8	4
Bus/tram/metro	17	11	9	8	2
Moped/scooter	1	1	1	1	1
Bike	24	25	25	25	26
Walk	20	19	18	18	15
Remaining	1	1	1	1	2

e.g. 'Urban >250k' shows the distribution of mode of transportation of people living in an urban area in a city with more than 250,000 inhabitants.

TABLE 4.8: Trip mode of transportation per urbanisation level and city size in % (OViN 2015)

In Table 4.7 and Table 4.8 the results of a more specified urban area can be found. The distribution of urban starting locations is not concentrated on big cities only. Also, smaller cities have areas with an amount of address per km^2 that falls into a higher urbanisation category. According to literature, car sharing is only viable in cities with a large number of inhabitants (>500,000) (Bert et al., 2016). To further explore the differences between rural and urban areas, an additional criterion is used to specify urban areas: number of city inhabitants. The provided city sizes from the OViN database are used. By combining the urban definition with the number inhabitants, the densely populated areas are used and the suburbs of the cities are excluded. The only cities with more than 250.000 inhabitants in the Netherlands are Amsterdam, Rotterdam, Den Haag and Utrecht. All these cities have either a metro, a tram, or both.

From Table 4.7 can be noted that the distribution of trip motivation for all density types are close. The difference between rural and very urban areas is at most 3%. There is no significant different in trip motivation between all the different areas.

Table 4.8 shows a big difference in mobility types per density. Cities with more than 250.000 inhabitants have half the amount of car driver trips of rural areas. The share of car passengers also decreases, but not proportional to the decrease in car drivers. The PT usage in bigger cities is a lot higher than in rural areas. Especially in the cities with more than 250,000 inhabitants, which is expected because these cities additionally facilitate a tram, metro, or both.

	Distance (km)			Time (min)			Speed (km/h)		
	Urban >250k	Urban	Rural < 50k	Urban >250k	Urban	Rural < 50k	Urban >250k	Urban	Rural < 50k
Car (driver)	20.4	18.0	18.4	29	25	23	41.9	42.6	47.4
Car (passenger)	16.9	17.3	17.7	28	25	24	36.8	40.9	44.8
Train	52.9	49.3	58.5	85	80	87	37.6	36.8	40.3
Bus/tram/metro	8.9	11.6	22.8	42	44	54	12.7	15.7	25.4
Moped/scooter	5.5	5.6	7.9	22	19	20	12.7	17.4	23.6
Bike	2.4	3.3	3.8	19	17	18	7.5	11.3	12.5
Walk	1.2	1.4	1.7	18	18	22	4.2	4.5	4.6
Remaining	20.9	21.8	25.3	40	41	41	28.3	31.6	36.8

TABLE 4.9: Trip distance, time and speed per mobility type per urbanisation level and city size in % (OViN 2015)

	Urban	Rural	Difference
0 – 15 years	21.1	21.4	*+0.3*
16 – 20 years	5.2	5.5	*+0.3*
21 – 25 years	5.0	3.9	*-1.1*
26 – 30 years	5.7	4.0	*-1.7*
31 – 35 years	6.1	4.2	*-2.1*
36 – 40 years	6.6	4.7	*-1.9*
41 – 45 years	7.1	7.3	*+0.2*
46 – 50 years	7.4	8.0	*+0.6*
51 – 55 years	7.8	7.9	*+0.1*
56 – 60 years	7.1	8.0	*+0.9*
61 – 65 years	6.3	7.4	*+1.1*
66 – 70 years	5.8	7.3	*+1.5*
71 – 75 years	3.7	4.7	*+1.0*
76 – 80 years	2.7	3.3	*+0.6*
81 – 100 years	2.2	2.3	*+0.1*

TABLE 4.10: Age distribution in urban and rural areas in % (OViN 2015)

Although the motivation of types does not vary significantly between different densities, the mobility types do. Urban areas with a high number of inhabitants drive significantly less by car and use the bus, tram, and/or metro significantly more as their transportation mode.

When comparing the average speed of trips of people living in small villages in rural areas (Table 4.9), the average speed in rural areas is higher for every mode of transport compared to urban areas and urban cities with more than 250.000 inhabitants. This does not mean that rural trips are also completed faster than urban trips. Only car trips take less time in rural areas. PT trips take longer in rural areas, but all other modes of transport take about the same time.

Next the demographics of urban and rural areas are compared. In Table 4.10 the different age distributions can be seen. Interesting to note is the large number of participants below the age of 12 in both areas. Their recorded movements were potentially influenced by the travel behaviour of their parent(s) or guardian(s). The share of participants in rural areas aged between 18 and 40 is lower than in urban areas, while the share of participants in rural areas aged between 41 and 100 is higher than in urban areas. The percentage differences are small.

	Urban	Rural	Difference
Daily	7.2	3.7	*-3.4*
Few times a week	12.0	4.1	*-8.0*
Few times a month	18.4	6.5	*-11.9*
Less than ones a month	25.0	20.8	*-4.2*
Almost never	37.4	64.9	*+27.5*
Unknown	0.0	0.0	*+0.0*

TABLE 4.11: Frequency of PT usage in urban and rural areas in % (OViN 2015)

	Urban	Rural	Difference
No means of transportation	2.0	0.7	*-1.3*
3 or more cars	3.3	7.8	*+4.5*
2 cars	27.2	39.9	*+12.7*
1 car	53.0	47.2	*-5.8*
Motorcycle	0.4	0.0	*-0.4*
Moped	1.5	0.4	*-1.1*
Bike	12.4	3.7	*-8.7*
Other	0.3	0.2	*-0.1*
Unknown	0.0	0.1	*+0.1*

TABLE 4.12: Owned means of transportation in urban and rural areas in % (OViN 2015)

In Table 4.11 the difference in frequency of PT usage is shown. Rural area inhabitants use PT significantly less, as they score lower in every PT usage case. In rural areas, almost 65% of the participants never use PT versus 37.4% in urban areas. This is a big difference, which confirms the earlier findings regarding the difference in means of transportation in the different areas. Although the difference in the 'almost never' category is big, the difference in daily PT usage is significantly smaller.

The noticeable differences in social participation (Table 4.13) in both areas are in division of retirees and workers. Rural areas have more retirees and people who work between 12 and 30 hours per week. Urban areas have more people who work more than 30 hours per week. The differences are small and can, given the limitations of the sample of the dataset, not be considered strong difference.

The differences between rural and urban areas have been analysed with a high level of abstraction. The obtained results indicate that in both areas the trip motivation is about the same, but that the use of means of transportation varies between the two. Rural area trips are more often performed by car, while urban area trips have a higher share of PT trips. By looking at the demographics, it was also found that rural area inhabitants use PT less frequently. The higher use of cars in rural areas was reflected in more households that own two or more cars. However, single car ownership was higher in urban areas. Although differences in age distribution in both areas was discovered, no significant differences in social participation were found.

The obtained answers give insight into the average distribution of trips and demographics of urban and rural areas and might not be true for specific areas. For a better estimation of the potential of specific areas, a detailed analysis of that area

	Urban	Rural	Difference
Working 12-30 hours per week	12.0	13.5	*+1.5*
Working more than 30 hours per week	31.9	29.0	*-2.9*
Household	4.4	5.1	*+0.7*
Student	20.7	20.5	*-0.2*
Unemployed	2.9	1.7	*-1.2*
Incapacitated	2.7	2.1	*-0.6*
Retired	16.2	19.7	*+3.5*
Other	1.9	1.9	*0.0*
Unknown	0.0	0.0	*0.0*
Not applicable: younger than 6 years	7.4	6.5	*-0.9*

TABLE 4.13: Social participation in urban and rural areas in % (OViN 2015)

needs to be performed. The results indicate that no significant difference between urban and rural demographics exists that could prevent car sharing from growing in both areas. The difference in current use and potential of car sharing in rural areas could be related to geographic reasons. A less densely populated area in theory means less customers. This theory is one of the reasons why less car sharing companies are active in rural areas. Furthermore, a lack of car sharing initiatives does not increase the number of customers, creating a vicious circle.

Question 2: First mile, last mile in PT

To look at the multimodality of travel behaviour, first the relevant multimodalities need to be defined. In the dataset, each journey has a main mean of transportation, while the trips that make up the total journey can be performed by various transportation modes. The analysed multimodalities are based on modes where either the train or the bus is the main mode of transportation. The number of metro and tram entries in the dataset is very low and only applicable in big cities and urban areas. Therefore, only journeys in which the train or bus is given as the main mode of transportation are looked at. The train journeys are made multimodal by using the bus, car, bike, or by walking. The bus journeys are made multimodal by using the car, bike, or by walking. The dataset does not contain any entries in which the bus is the main mode of transportation and the train is one of the trip types during this journey.

The data from the dataset used for this analysis is cleaned by removing entries that do not have a departure and arrival postcode, a travel distance, or departure time. The choice was also made to set the minimum age of respondents to 18 years old. Car sharing users in the Netherlands need to be at least 18 years old because a driver's license is required. Of the total 115,987 trips, 74,088 trips remain to be analysed.

Of these trips, 5343 (7.2%) were trips in which the main mode of transportation was a train. Of these trips, 1741 were performed by train. The remaining 3602 trips were performed by other means of transportation and used to get to or away from a train station. An overview of these trips can be found in Table 4.14. The number of remaining trips is more than twice the number of train trips, which could mean that every train trip in the dataset has a trip to get to and from the train station, a first mile and a last mile. Of these remaining trips, about half (46.5%) is completed by foot and one-fourth (24.9%) is completed by bike. The bus is used for 13% of the trips. 3% of the trips are performed by people who switch to or from a car during their journey. This is a low amount given the large parking structures and Park&Rides near train stations. The car drivers and passengers categories cannot be combined, because car passengers can be dropped off while the driver continues their journey somewhere else without using the train.

Next, the multimodality of bus journeys is reviewed. In total 1928 trips are recorded in the database where the bus is the main transportation mode. 911 of these trips are performed with the bus. That leaves 1017 trips performed with other modes of transportation. In Table 4.14 the trip division for bus as the main transportation mode is given. The number of additional trips is not twice as big as the number of bus trips, as was the case with the train trips. This means no first and last mile are recorded for every bus trip. A possible explanation could be that buses provide a better door-to-door service, thus not requiring additional travelling after the bus trip is finished. This is confirmed by the large share of walking (83%) as extra mobility. The distances that need to be covered before or after a bus trip are relatively short. Biking is used a lot less in combination with bus travel, than with train travel, reflected in the 14% decrease. The share of car drivers remains roughly the same, while no record exists of combined bus, and tram, or metro travel, where the bus is the main mode of transportation. With the metro or the tram as the main means of transportation, a combination with buses in one journey exists. Also, no journey exists in which the bus is the main mode of transportation and the train is used as part of the journey.

In Table 4.15, the average waiting times for either the train or bus is shown for

	Number of trips		Percentage of trips		
	Train	Bus	Train	Bus	Difference
Train	-	0	-	0	-
Bus	467	-	13.0	-	-
Car driver	111	33	3.1	3.2	*+0.1*
Car passenger	124	21	3.4	2.1	*-1.3*
Tram	156	0	4.3	0.0	*-4.3*
Metro	162	0	4.5	0.0	*-4.5*
Walk	1669	847	46.3	83.3	*+37.0*
Bike	892	112	24.8	11.0	*-13.8*
Moped	6	2	0.2	0.2	*+0*
Other	15	2	0.4	0.2	*-0.2*
	3602	1017	100%	100%	

TABLE 4.14: Different means of transportation used in journey with train or bus as main means of transportation, in amounts and percentages (OViN 2015)

	Train	Bus	Car	Bike	Walking	Average
Train	-	8:05	8:10	6:38	6:37	6:53
Bus	-	-	6:02	5:41	4:10	4:21

TABLE 4.15: Average waiting times when switching to train or bus from other mobility type in minutes (OViN 2015)

each of the additional modes of transportation. The times show the difference between arrival time with the given transportation mode and the departure time of the train or bus. Since people are asked to indicate their arrival time, a difference between interpretation can exist. Some people might fill in their arrival time at a parking space, while other might fill in their arrival time at the correct departure platform. Therefore, it is difficult to draw conclusions from this overview. It is useful as an overview of the differences that exist. A maximum waiting time of 60 minutes has been set, because some trips indicated a waiting time of over five hours. The limit of one hour has been chosen, because most PT has a frequency of at least once an hour. This disproportionality is most likely caused how people filled in the survey. A waiting time of five hours indicate that they ended their journey and performed some activity. But the journey in the dataset continues and ends when they are back home again. The 60 minutes waiting time limit, lowered the average waiting time from walking to the train with two minutes. The waiting times caused by switching from bus to train, or car to train or bus are above average. The share of car drivers in the scenarios where the train or bus are the main transportation mode are low ($\approx$3%), as was discussed in the previous section. Therefore, outliers have a bigger influence on these average waiting times. The waiting times for switching from a car to a bus are two minutes shorter than for switching from a car to a train, but is still higher than the average of its category.

In Table 4.16 the motivation of the different multimodal trips is given. Multimodal trips are mostly used to commute, with only the train and bus journey more used for educational purposes. Education related trips are the second largest motivation

	Train				Bus		
	Bus	Car	Bike	Walk	Car	Bike	Walk
To/from work	28.1	48.6	55.0	45.8	60.6	51.8	34.6
Business visit	0.4	0.0	2.9	2.2	3.0	0.0	1.1
Services/Personal care	3.2	0.0	1.3	1.4	0.0	0.0	9.4
Shopping/Groceries	2.1	6.3	4.4	4.4	6.1	7.1	16.8
Education	40.3	18.9	17.9	20.4	6.1	19.6	13.3
Social visit	12.8	9.9	7.0	11.7	6.1	5.4	10.3
Social recreation	9.6	10.8	8.2	10.8	6.1	13.4	11.5
Tours/hiking	0.9	0.9	1.1	0.6	0.0	0.9	0.8
Different	2.6	4.5	2.1	2.6	12.1	1.8	2.2

TABLE 4.16: Motivation of multimodal journeys with train and bus as main trips in % (OViN 2015)

category in most multimodality journeys. The exception is the combination of bus and walking, where shopping activities are more common. while in theory the bus does not provide a lot of room for baggage.

Table 4.17 shows an overview of the distance that every part of a multimodal trip covers. An example will be given of the first column. If the train and bus are used together in a journey, 30.7% of all the train trips are at least 50 kilometres and 27.6% of all bus trips are between 5.0 and 7.5 kilometres. In bus and car multimodality trips, the car is used for a longer distance than the bus trips, as a higher percentage of bus trips are shorter distances. This is not the same for the multimodal train and car journeys. For those journeys, the train is used to travel the furthest distances.

Finally, the demographics of the discussed multimodality groups are discussed to provide more context to the talked about findings. Table 4.18 shows an overview of relevant demographic related categories found in the dataset. Each section in a column adds up to 100%.

Most transportation combinations show a higher usage in more urbanised areas, but the train and car combination is mostly used in hardly urbanised areas and relatively little used in extremely urbanised areas. Train and bike multimodal journeys are mostly present in extremely urban areas and to a lesser extent in strongly urbanised areas. The bus and bike combination is mostly preferred in strongly urbanised areas as a multimodality journey.

Both the categories where the bus is the main mode of transportation show a distinct user age group. A large share of the users is 20–29 years old or 45–54 years old. However, it should be noted that the bus and car combination has gaps for the 20–24 and 55–64 year old categories. This is most likely caused by a limited sample size. The train and bus mobility combination shows a large share of 20–24 year olds. These are most likely students, as the student share in the social participation is high (42.9%).

In all other multimodality categories is the people in employment group is the biggest. This can be biased, because most citizens in a country are usually workers. The preferred multimodality type of retirees is by train and car.

	Train + bus		Train + car		Train + bike		Bus + car		Bus + bike	
	Train	Bus	Train	Car	Train	Bike	Bus	Car	Bus	Bike
Not in NL	0.0	0.0	0.0	0.9	0.0	0.0	0.0	2.9	0.0	0.0
0.1–0.5 km	0.0	0.4	0.0	0.0	0.0	1.4	0.0	0.0	0.0	7.8
0.5–1.0 km	0.0	2.8	0.0	1.8	0.0	5.6	2.6	0.0	0.0	18.1
1.0–2.5 km	0.8	19.3	0.0	15.0	0.6	52.1	33.3	2.9	4.0	50.0
2.5–3.7 km	0.2	14.4	0.0	12.4	0.1	20.2	25.6	2.9	4.0	16.4
3.7–5.0 km	1.0	7.5	0.8	4.4	0.0	8.9	12.8	5.7	0.8	1.7
5.0–7.5 km	3.6	27.6	4.0	20.4	2.7	9.8	7.7	8.6	10.3	5.2
7.5–10 km	2.3	5.5	4.0	9.7	4.1	0.9	2.6	2.9	19.8	0.9
10–15 km	8.6	12.4	8.1	12.4	8.5	1.1	5.1	8.6	23.0	0.0
15–20 km	12.2	5.1	8.9	6.2	9.9	0.0	0.0	17.1	15.9	0.0
20–30 km	17.0	4.1	13.7	12.4	20.4	0.0	5.1	11.4	11.9	0.0
30–40 km	13.2	1.0	7.3	1.8	16.1	0.0	0.0	11.4	4.0	0.0
40–50 km	10.5	0.0	7.3	0.0	11.2	0.0	0.0	5.7	3.2	0.0
>50 km	30.7	0.0	46.0	2.7	26.3	0.0	5.1	20.0	3.2	0.0

TABLE 4.17: Distance distribution of multimodal train and bus trips in %, e.g. within a train and bus multimodal journey, 30.7% of the train trips is longer than 50 kilometres (OViN 2015)

The multimodality travel which includes travel by car, shows a higher car ownership share than multimodality travel without car. For multimodality journeys without cars, the bike ownership is higher.

The non-car related multimodality journeys show a larger share of higher frequency of PT usage. Notable is that train and car multimodality show a high percentage of PT travel of less than ones a month. The recorded trips in the dataset might just have coincided with the incidental PT travel for that month.

4.4 Conclusion

From the obtained results from the analysis, conclusions will be drawn. The conclusions are limited by the sample size of the dataset. Although the dataset contained over 115,000 entries, only a small number of those entries possessed the looked-for characteristics. Both research questions will be repeated and then answered. Finally, the question related to this chapter will be answered.

Question 1: Urban versus rural

What are the differences and similarities between urban and rural travel patterns?

The travel patterns of both areas have been analysed by looking at trip characteristics, such as means of transportation, motivation, distance and time, and demographic characteristics, such as age, occupation, and PT usage frequency.

A striking similarity between both areas is the division of trip motivations. The main motivations in both areas are (grocery) shopping, social recreation, and commuting. No significant difference was found between the distribution of trip motivation. Also, the social participation showed big similarities. Differences were found in the share of retirees and workers, but these differences were small. The other social participations have evenly matched shares.

However, big differences were found in the modes of transportation between both areas. Cars have a higher usage share in rural areas, especially compared to urban areas in big cities. The lower car usage in urban areas is replaced by more PT usage, while the bike share remains roughly constant. The higher the urbanisation of an area, the lower the car driver travel share, and the higher the PT share. The larger share of car usage in rural areas is also reflected in the higher number of households in rural areas with 2 or more cars. However, urban areas have a higher single car ownership. Urban areas were found to have a larger share of people between the age of 20 and 40, while rural areas were found to have a higher share of people between the age of 60 and 70. The age group in urban areas was also found in literature to be the age group of the majority of current car sharing users. As was discussed in chapter 2, this age group is often the early adopters of new technology. The trip characteristics show that trips in rural areas cover a longer distance, but take less time. Every mode of transportation in rural areas has a higher average speed compared to urban areas.

Question 2: First mile, last mile in PT

What are characteristics of the first and last mile of a PT trip?

To analyse the characteristics of multimodal PT trips, different multimodality trips were defined. The train and the bus were chosen as two main mobility categories. Travelling by car, bike, and walking were defined as additional mobility modes. In the case of train travel, the bus was also considered an additional mobility type.

The ability to draw conclusions from the findings is limited by the uncertainty of the accuracy of the filled in data by the participants of the survey. For example, it was found that half of all the multimodal bus journeys were actual bus trips. This means bus trips only have a first or a last mile.

Walking is part of the majority of multimodal trips, both for train and bus. The second largest multimodality mode of transportation is the bike. The share of cars within multimodal trips is small, but constant in both the scenarios. The waiting times to switch from car to train or bus were found to be significantly longer than for switching from bike or walking.

The main motivation for people to perform multimodal trips are commute trips, with education related trips in second. Combining train with bus was found to be most used for education related trips. This was also found by looking at the age and social participation of this group. Multimodal train journeys which involved cars were found to be performed mostly in hardly urbanised areas. This can be related to the first research question of this chapter as it shows potential for car sharing in hardly urbanised areas. Multimodal trips seem to attract a specific age group, as some age groups are over represented. However, given the limitations of the sample size, it can be caused by a lack of more data entries.

Chapter question

What kind of candidate features can be found in or deduced from travel behaviour?

The two studied areas show large similarities and few differences. Rural areas show a higher car usage and ownership than urban areas, which indicates that the infrastructure and trips are suited for car sharing. However, the difference between the two areas could be related to the lower population density. Car sharing should offer the same reliability in these areas as in higher density population areas. This can be more difficult because a lower population density means less demand per car location. As was found in chapter 3, a car sharing parking location close to one's house increases one's use incentive. Car sharing should incorporate a mechanism to supply cars where demand exists, to create a reliable service.

The higher number of cars per household in rural areas could be a focus point of a market strategy in rural areas. By creating awareness about the amount of time a car spends stationary each day and the fixed amount of money car ownership costs, the financial benefit of car sharing could become a major selling point. Especially if no mobility is lost.

The analysis of multimodality showed that the car is barely used in combination with the bus or train, as was also found in chapter 3. Multimodal trips with cars were mainly commute trips. As found in literature, commute trips are predominantly performed by one-way car sharing services.

Multimodality can be increased, and waiting times can be decreased, by informing users about PT connections, expected arrival times and delays.

	Train			Bus	
	Bus	Car	Bike	Car	Bike
Level of urbanisation					
Extremely urbanised	33.7	9.3	37.2	15.2	18.6
Strongly urbanised	32.6	20.7	32.8	32.6	49.2
Moderately urbanised	17.1	23.1	14.3	18.2	12.0
Hardly urbanised	13.5	42.1	12.1	14.4	15.0
Not urbanised	3.1	4.8	3.5	19.7	5.2
Age					
18 – 19 years	11.7	3.7	6.9	3.0	5.7
20 – 24 years	34.8	17.0	22.2	0.0	25.4
25 – 29 years	9.5	14.3	11.5	33.3	17.2
30 – 34 years	4.9	5.7	8.6	4.5	4.1
35 – 39 years	5.3	0.0	10.1	5.3	6.6
40 – 44 years	4.7	4.0	8.9	3.8	1.4
45 – 49 years	4.4	18.1	9.5	25.0	10.0
50 – 54 years	5.5	9.9	8.5	18.2	20.0
55 – 59 years	6.8	5.9	7.0	0.0	6.1
60 – 64 years	5.1	4.8	2.5	0.0	0.0
65 – 69 years	2.1	7.3	3.4	3.8	2.7
70 – 74 years	2.9	7.7	0.7	3.0	0.9
75 – 79 years	0.9	1.5	0.0	0.0	0.0
80 years or older	1.5	0.0	0.2	0.0	0.0
Social participation					
Working 12-30 hours per week	11.6	13.7	15.2	22.7	17.5
Working more than 30 hours per week	32.2	49.1	51.6	53.8	46.5
Household	1.2	1.5	1.1	0.0	1.6
Student	42.9	19.8	24.6	16.7	23.4
Unemployed	1.3	0.9	0.9	0.0	4.1
Incapacitated	0.4	0.0	0.7	0.0	1.1
Retired	8.2	15.0	4.5	6.8	3.6
Other	2.1	0.0	1.4	0.0	2.3
Unknown	0.0	0.0	0.0	0.0	0.0
Owned means of transportation					
No means of transportation	1.3	0.0	0.0	0.0	0.0
3 or more cars	3.1	11.2	1.9	13.6	3.2
2 cars	20.1	47.1	15.4	30.3	23.6
1 car	45.3	38.3	51.3	42.4	52.2
Motorcycle	0.5	0.0	0.8	0.0	0.0
Moped	0.0	0.0	1.9	0.0	0.9
Bike	29.4	3.3	28.3	13.6	20.2
Unknown	0.0	0.0	0.4	0.0	0.0
Public transportation usage frequency					
Daily	47.6	39.0	46.1	30.3	44.7
Few times a week	40.7	27.8	41.8	31.8	38.1
Few times a month	7.8	16.3	8.7	33.3	11.1
Less than ones a month	3.6	17.0	3.1	0.0	6.1
Almost never	0.4	0.0	0.4	4.5	0.0

TABLE 4.18: Demography of different multimodal trips in % (OViN 2015)

Chapter 5

Car sharing features

In this chapter, the found candidate features will be discussed. First, the criteria a feature needs to comply with are considered. Secondly, the found candidate features will be presented. Thirdly, the compatibility of features will be examined. Fourthly, the dependency of features on each other or external sources is investigated. Finally, recommendations are formed.

5.1 Criteria

As was defined in chapter 1, a feature is a distinctive attribute or element which, when implemented correctly, profits/benefits (or at least not harms) at least one stakeholder group. The considered stakeholders involved with car sharing are users, car sharing companies, governments, and the environment. During the feature gathering phase, the perspective of users was used. However, when assessing the possible implementation of a feature, all stakeholders need to be considered.

The main preferences of the different stakeholders are now sketched on an abstract and simplified level.

Users of a car sharing service want a service that offers them the same mobility as owning a car, with a lower cost. Convenience is a big priority.

Car sharing companies want to capture and expand their market share, offer a better service than their competitors, and earn money.

Governments (local and central) want to provide citizens with a high level of mobility to improve area accessibility and attractiveness.

The *environment* wants reduced pollution, and less emission of harmful gases.

Stakeholders could have conflicting interests. For example, users want a cheap service and spend as little money as possible. Service providers on the other hand want to make a profit and need to ask an at least cost covering price.

Features should work together to create a better service. If a feature is countering the effects of another feature, the positive effect is weakened or reversed.

It should be feasible for car sharing companies to implement a feature. Feasibility can, for example, be measured in terms of costs or implementation time. If a feature would take multiple years to be correctly implemented and is not vital for the current functioning of the service, risks arise. It is unknown whether the feature would still be desired in the future.

Feature	Summary
Trip types	
Round trips	The start and end location of the rental period are identical
One-way trips	The start and end location of the rental period can be different
Dedicated parking spaces	
Station based	When not being rented, a vehicle is positioned at a dedicated parking spot
Free floating	When not being rented, a vehicle can be positioned at any public parking spot
Reliability	
Availability	The assurance that when needed, a vehicle is always at one's disposal
Accessibility	The distance between user and vehicle start location should be minimal
Up-to-date vehicles	The vehicles are well maintained, do not break down, and fuel-efficient
Flexibility	
Different types of vehicles	Depending on the travel needs, an appropriately sized vehicle can be chosen
Low reservation time	Spontaneous trips can be undertaken
Cost education	
Insight into savings	Provide (potential) customers with more understanding about the financial side
Personalisation	
Planning	In advance route planning shows mobility alternatives and PT possibilities
Travel information	While renting, information is provided about travels changes and delays
Discount	Customers are rewarded for ending rental periods in optimal demand locations
Key cards	Customers can register their own card to open a car
Autonomous vehicles	
Vehicle repositioning	Vehicles automatically reposition themselves to areas with (potential) demand
Taxi fleet	The whole car sharing fleet is made autonomous and functions as a taxi service

TABLE 5.1: Overview and one sentence summary of the found candidate features in the previous chapters

5.2 Overview

In this section, the candidate features found in the previous chapters are discussed. An overview of the features can be found in Table 5.1.

The primary differentiating feature between different car sharing services is the degree of freedom to pick a location to end a rental period. *Round trip car sharing* requires users to end their rental period at the same location as the starting location, while *one-way car sharing* allows users to end their rental period at a different location than their starting location. This difference attracts different usage patterns and creates different market potentials. One-way requires more planning, as the geographic distribution of vehicles can change over time.

Another feature that defines the degree of freedom granted to users is the usage of *dedicated parking spaces* for car sharing cars. *Free floating* services offer their users the freedom to park the car wherever they want, given some predefined area limitations. *Station based* services limit the freedom of users by restricting them to use a particular parking space, but reward users by offering them a parking spot. This removes the stress induced by searching for a parking spot. Also, no additional parking fees need to be paid. The fixed places to park also make it easier for users to remember where they can pick up a vehicle and start their journey. Through governmental collaboration, car sharing companies can position parking spots in or close to areas with high demand.

Offering *reliability* was found to be very important. Travellers want to be assured that they can finish their journey once started. *Availability* of cars is crucial for the reliability of the service. Therefore, a geographically well-distributed vehicle fleet with cars available at places with demand is required. Correct demand estimations are important to be able to provide this availability.

Reliability is influenced by *well-functioning vehicles*. When a car breaks down, the fleet size decreases and the driver has a bad experience. Therefore, vehicles need to be well maintained and timely replaced. An advantage of this is that the fleet is kept up-to-date with technological and fuel efficiency improvements.

By keeping the required *reservation time* low, spontaneous and unplanned trips can also be performed by car sharing. A short minimal reservation time increases the flexibility of the service and mimics the characteristics of owning a car.

A way to offer more mobility than a private car would, is giving people the ability to choose between *different vehicle sizes*. Different travel motives could require specific types of vehicles, such as a vehicle with a large trunk when buying furniture. It is important to inform and educate users about the various vehicle types, to have their mobility needs fulfilled correctly.

It is also important to educate (potential) users about the *costs* of car sharing. The removal of fixed costs compared to car ownership are considered important and seen as a big motivation to start using car sharing. However, the costs of a car sharing trip, calculated in terms of distance and/or time, are perceived as high. By giving an estimation of the trip costs beforehand, the user does not get an unpleasant surprise when the trip is ended. Another way to make the financial benefits more evident is providing more *insight into the savings* which can be achieved with car sharing. This can, for example, be achieved by letting users calculate the amount of money they could save when replacing their current private car usage by car sharing.

Other forms of information and *personalisation* are also important. During a trip, information can be provided about delays on the road or in PT. This offers users the ability to be extra flexible and change their route on the fly. Personalisation can also happen in the form of discounts. For example, it can be used to motivate a user to end his rental period in an area with (potential) demand. In return, the user gets a number of free kilometres for his next usage.

Car sharing can offer a level of *convenience* that other mobility types cannot offer. Convenience and personalisation can be improved by allowing users to open a car with something else than a company provided card. For example, by using their PT card, mobile phone or registering their own card (e.g. drivers licence). This decreases the possibility of missing the necessities to open a car.

Integration of *autonomous vehicles* could evolve the current car sharing implementation. An autonomous taxi fleet could be created which can pick up and drop off people anywhere they want. Or in a less disruptive scenario, it can be used to reposition cars from areas with low demand to areas with high demand.

5.3 Compatibility

In this section, the compatibility of features is discussed. First, features are compared against each other for consistency. Secondly, the compatibility of the features in terms of the different stakeholders is discussed.

5.3.1 Feature combinations

Two conflicting features are either offering *one-way* or *round trips*. The companies on the market have all chosen one or the other as specialisation. Round trip prohibits one-way trips, but one-way allows round trip journeys, as the user is also allowed to return to his start location. Implementing one-way trips requires more active planning because the vehicles are not returned to the same location. Therefore, the geographic distribution of the vehicles could change.

When creating a *P2P-based car sharing* service, it is impossible to offer a *one-way* trip service. Even if no physical transfer of car keys is needed. The people who lease out their car want to know when their car returns, otherwise they compromise their own mobility.

Combining *one-way* and *station based* car sharing limits the freedom provided by the one-way trips. When a user is obligated to use a company provided parking spot, his destination location flexibility is limited. The advantages of a dedicated parking place are not applicable in all scenarios, as parking places are not always close to the destination of a user. One-way in combination with free floating provides the same mobility as a private car would.

The advantages of *dedicated parking spots* seem to be very important for current users. However, it could be argued that parking spots would not be useful when car sharing is transformed into an *autonomous taxi network*. The cars do not need to be parked and can drive around until somebody requests their services. This would make investments in parking places not future proof. However, the usage and visibility of parking spots could still be an advantage, especially at transportation hubs. The parking spots can be used as easy pick up locations and reduce the fuel consumption of not used vehicles.

5.3.2 Stakeholders

The candidate features described in section 5.2 were found by using the user perspective. In this section, the benefits for the other stakeholders is checked. Not all features are relevant for each stakeholder. Therefore, only the relevant features for each stakeholder will be discussed.

Car sharing companies

Of the supported trip types of car sharing, *one-way trips* provide its users the most freedom. However, it is the most difficult trip type for companies to implement correctly, especially in combination with free floating. If a balanced distribution is not automatically created, additional balancing needs to be done. One possibility is to hire people to manually reposition vehicles. However, this is very expensive and inefficient. Another possibility is to motivate users to end their rental period in an area with high demand by offering them discounts or achievements. Planning software to automate this process would need to be created.

Although the creation of *dedicated parking spots* costs money, time, and effort, it can be very beneficial for car sharing companies. It provides recognisability and is effectively advertisement. It was found to be a wanted feature by many users. Not having to search for a parking spot removes one of the disadvantages of driving a private car.

Companies want to supply their customers with reliable vehicles, which means regular maintenance and replacement of vehicles. Keeping the *vehicles up-to-date* is a disadvantage, because it means that companies need to keep reinvesting in car inventory without expanding the fleet size. On the other hand, by replacing older cars with more fuel-efficient cars, fuel costs can be reduced.

Offering *different vehicle sizes* is beneficial for users, as they can pick a suitable car for different travel needs. This creates a heterogeneous vehicle fleet. This is a disadvantage for car sharing companies because it makes vehicle distribution and maintenance more difficult. Within the normal vehicle distribution, the different types of vehicles also need to be distributed. Otherwise, the different vehicles types cannot be exploited by all users.

The *implementation of AVs* into the vehicle fleet is advantageous for car sharing companies, independent of the willingness of people to ride in an AV. For example, people could still be allowed to drive in the vehicles, and the autonomous functionality could only be used to reposition the vehicles. This removes the need for manual repositioning, which has a high operating cost. Companies can invest in software that optimises the repositioning of AVs to areas with high demand.

Government

By actively working together with car sharing companies, governments can adapt the planning of certain areas and incorporate car sharing *parking places*. Both in new and already developed areas. This allows them to increase the mobility of their inhabitants.

A vehicle fleet consisting of *up-to-date vehicles* has the advantage of lower emissions. Transportation is a big part of the total CO_2 emissions. Lower emissions are important for governments as they are required to meet emission reduction goals.

One of the probable advantages of an *autonomous taxi fleet* is the reduced parking need. The size of the total fleet of vehicles can be reduced, leading to less cars requiring a parking place. This allows governments to reallocate the ground currently occupied by parking structures.

Environment

The availability of cars is very important for the reliability of car sharing. The availability of cars can be increased by expanding the vehicle fleet. However, for the environment a *small fleet size* is more beneficial, as the manufacturing of cars also emits harmful gases.

An advantage for the environment is the timely replacement of older vehicles. Fuel-efficient vehicles are a result of keeping the *fleet up-to-date*. The disadvantage of emission of harmful gases during the manufacturing of the cars is also applicable in this situation.

The transition of car sharing into an *autonomous taxi fleet* could also be beneficial for the environment. AVs are expected to be more fuel-efficient and likely not powered by fossil fuels.

5.4 Dependency

In this section, feature combinations are discussed which can only be implemented together, require collaboration, or need additional technological advancements before they can be implemented.

Round trip car sharing is mostly used in combination with *station based parking*. When a car is not being used, it is parked on a dedicated parking space. This gives the user the guarantee that a parking place is always available when returning to the starting location to end the rental period.

Creating *dedicated parking spaces* requires *permission* of and *collaboration* with (local) governments and policy makers. The parking spaces have to be paid for, but in return, collaboration provides companies with more business contacts and better integration into the existing infrastructure.

Feature	Importance	Implementation difficulty	Stakeholder compatibility		
			CSO[a]	Gov[b]	Env[c]
Trip types					
Round trips	Must	Medium	-	-	-
One-way trips	Must	High	-	-	-
Dedicated parking spaces					
Station based	Must	Medium	High	High	-
Free floating	Must	Medium	-	-	-
Reliability					
Availability	Must	High	-	-	Low
Accessibility	Should	Medium	-	-	-
Up-to-date vehicles	Should	Medium	Medium	High	Medium
Flexibility					
Different types of vehicles	Could	Medium	Low	-	-
Low reservation time	Should	Low	-	-	-
Cost education					
Insight into savings	Should	Medium	-	-	-
Personalisation					
Planning	Could	Low	-	-	-
Travel information	Could	Low	-	-	-
Discount	Could	Medium	-	-	-
Key cards	Could	Low	-	-	-
Autonomous vehicles					
Vehicle repositioning	Should	High	High	-	-
Taxi fleet	Should	High	High	High	High

[a] Car sharing organisation
[b] Government
[c] Environment

TABLE 5.2: Detailed overview of the found and discussed features labelled with importance, implementation difficulty and stakeholder compatibility

To provide users with additional *trip information* during their journey, a way to communicate or display information is required. The entertainment and navigation system in cars is a closed system, only accessible to the *car manufacturer*. No third party, in this case a car sharing company, can utilise this system. For example, if a user uses the cars built-in navigation system during the journey, no extra information can be added to this system. Collaboration between car manufacturers and car sharing companies would be required for vehicle-user interaction. This would be difficult to realise for independent car sharing companies, but for car sharing companies founded by car manufacturers, such as Car2go (Daimler/Mercedes-Benz) and DriveNow (BMW), this could be a more feasible solution. For other car sharing companies, mobile phones could provide a solution. Each car can be equipped with a smartphone holder, positioned to facilitate navigation. Mobile phones should not be physically interacted with while driving, so additional information should either be provided in speech or in warning sounds.

AVs are still in an *experimental phase*. Various estimations have been made regarding the time frame of release of AVs to the general public, but no one knows for certain. The described effects of AVs are the expected impact, as no real-life examples of AV fleets exist yet. AV technology needs to be further developed before it becomes available to the general public and can be implemented in car sharing.

5.5 Recommendations

With the candidate features analysed, a new table can be created to summarise the findings. In Table 5.2, features are given an importance and implementation difficulty rating, as well as a compatibility rating with the different stakeholders.

The importance of features is categorised using the MoSCoW method (Vliet, 2007). This method has four qualifiers to identify the priority of requirements or in this case features: (1) Must haves, this feature is needed, and the service will not function correctly without it, (2) Should haves, this feature is important, but not crucial for a usable service, (3) Could haves, features that will only be implemented when time is available, (4), Won't haves, the feature will be left out, but might be used in a future iteration. The table was filled in based on the perceived importance from the previous chapters. For example, inferred features are rated with a lower priority than features found in existing services and literature.

Although conflicting and dependent features were found, no "won't have" features were identified. Car sharing will not have AVs yet, but should in the near future start experimenting with them. When the tests are successful, the importance might change from should have to must have. Within the trip types and dedicated parking spaces category, all the features have been given the must have identifier. However, within each category, a choice needs to be made for one of the features. This choice will create the foundation upon which the car sharing service will be built, so it is an important choice.

The implementation difficulty of features was rated on a three-step scale ranging from high to low difficulty. The rating is based on expected implementation time and costs required to successfully implement the feature.

The stakeholder compatibility is derived from the discussion of stakeholders in subsection 5.3.2 and ranges from high to low compatibility. Only the discussed compatibilities are shown in the table, the rest is noted with a '-'. High compatibility means that the feature is beneficial for the stakeholder, while low compatibility means implementation is disadvantageous for the stakeholder. Medium compatibility means no direct influence, or both advantages and disadvantages exist. For example, keeping the vehicle fleet up-to-date is rated as medium compatibility for car sharing organisations. Potential benefits are lower maintenance costs, less car failures, better environmental image, and lower fuel costs. However, potential disadvantages are mostly financial, as companies need to keep reinvesting in vehicles, and new vehicles have a higher depreciation. No weighting factors have been determined, so it is impossible to say which advantages and disadvantages have a higher importance. Therefore, the compatibility has been labelled as medium. Car sharing organizations must make their own decision.

5.5.1 Research question

The research question that this thesis tried to answer is:

What are the key design features of a shared vehicle fleet to stimulate adoption and social support amongst the general public?

A list of features has been created, but this list is not set in stone. The list can be changed, by adding or removing features. Car sharing companies need to decide which features they want to implement. Features that must be implemented, should be looked at first. The distinction between offering round trips or one-way trips should be made, followed by whether dedicated parking spaces will be provided. The type of trips, location and demographics that the company wants to facilitate, should be used as a guide for picking the most fitting implementation. Secondly, a plan needs to be made and implemented on how to guarantee vehicle availability to users, as availability is crucial for good user experience. Thirdly, features with high importance, low implementation difficulty and high stakeholder compatibility should be considered. A feature fitting these criteria is the low reservation time. Fourthly, the personalisation of the service should be looked at. Although not high on the importance list, its implementation difficulty is estimated to be relatively low. These extra features could distinguish one service from another.

Before these decisions are made, car sharing companies need to get to know their target audience and their needs. Car sharing services should fit to their users, and not the other way around. By understanding the decision-making behaviour to join a car sharing service, car sharing can be made more attractive (Kim et al., 2017).

Marketing and consumer education could be used to reach and attract a wider audience. These channels can be used to explain the individual and society-wide benefits of car sharing. The willingness to join and use a car sharing service is higher, if people know about car sharing (Dieten, 2015). Not only the adoption is increased. If the benefits for society are also established, social opinion will be in favour of car sharing.

It should be noted that caution needs to be taken if car sharing is expanding too quickly. B2C car sharing requires large financial investments to scale with the growth of the user base. If the size of the vehicle fleet cannot keep up with the size of the demand, the availability of cars drops. Low availability leads to bad user experience and unhappy customers. Therefore, growing too fast could be destructive for the long-term future of car sharing. A steady growth rate at which the fleet size can keep up with demand is ideal.

Chapter 6

Conclusion and outlook

In this chapter, conclusions are drawn about the opportunities identified in chapter 1. Next, the used information sources are discussed and evaluated.

6.1 Conclusion

The current market share of car sharing does not match the potential estimated in literature. To determine how the estimated potential can be reached, various unexploited opportunities for car sharing have been identified and explored. The goal was to find features that would increase the utilisation and acceptance of car sharing as a capable mobility alternative. The traveller's perspective was taken to find mobility preferences, and identify wanted and unwanted features. Three existing information sources (literature, online reviews, and a mobility dataset) were identified and analysed.

In literature, car sharing was found to be mostly used for shopping, and social activity related trips. The reduced fixed costs are the main motivation to join a car sharing service. The opportunity of AV technology for car sharing was also identified in literature. AVs can be used to create an autonomous taxi network. This decreases the number of cars required for everybody to fulfil their travel needs and increases the amount of potential car sharing users.

By studying online reviews, a better understanding of the users of car sharing was created. Although car sharing companies with PT collaboration were researched, no reviews were found discussing this collaboration.

The mobility dataset was investigated to find PT integration in the recorded journeys. Multimodality with either bus or train, was observed in a small share of the journeys. Within this share, cars were not a common means of transportation in a PT multimodality journey. However, influencing factors have been identified, such as transfer times and the level of urbanisation.

The mobility dataset was also used to determine mobility differences in urban and rural areas. No significant differences in trip motivation and demographics were found. The means of transportation used in both areas did differ. In rural areas, more journeys were performed by car, but less journeys were performed with PT.

From each information source, various candidate features appeared. These features have been reviewed and evaluated according to defined criteria. Combinations of features were checked, as well as potential benefits of features for the considered stakeholder groups. By involving different stakeholders in the evaluation of the found features, the initial focus on (potential) customers has been balanced.

It is argued to be impossible to implement all the found features. Not all feature combinations improve car sharing or are deemed beneficial for one or more of the stakeholders. Furthermore, not all features can be implemented yet. Some features require more advanced technology, while others require intensive collaboration between multiple parties. Through collaboration and technological advancements, existing features will evolve and new features will arise. Flexibility of car sharing services is important to be able to adjust to partner and market needs.

This research provides insights from the consumer perspective on mobility, which can be used by different parties as guidelines to improve car sharing or mobility in general. It can be used by governments and policy makers to explore the potential benefits and requirements of incorporating car sharing into their current PT set-up. Car sharing companies can further investigate the proposed features and check the feasibility for their specific service. For researchers, this paper provides an overview of the available car sharing literature and presents alternative information gathering methods. These methods can be expanded and adjusted to fit to other locations of interest in future research.

6.2 Discussion

By combining conventional and unconventional information sources for car sharing research, new insights have been found. The three information sources will be discussed and evaluated.

Literature is a commonly used information source and was expected to give clear insights into already researched implementation possibilities of car sharing, since a lot of car sharing studies can be found. However, some of the discussed literature showed inconsistent findings. These inconsistencies show that the success of car sharing is highly dependent on context and external influences, and can be an explanation for the lack of a success formula for car sharing. The literature does not agree on a uniform service to fit the criteria of all potential users.

Using online reviews is less conventional, but provided information that would be difficult to obtain via surveys. The results represent what people deem important enough to take the initiative themselves and to post online. The ability to draw generalisable conclusions is limited by an unknown sample distribution and by the number of reviews found in Dutch. This method is valuable for idea generating, but should, given its limitations, not be used to validate findings from other sources.

The daily mobility dataset contains a lot of entries and shows the travel pattern of one specific day of a participant. If not zooming in on specific journey types, the sample provides a lot of entries. However, when zooming in on very specific behaviour, the sample size becomes small. This makes it difficult to draw conclusions. By enriching the data with other datasets, more information can be collected. By matching similar areas, for example, by comparing the proximity of services in the vicinity (CBS, 2016c), the results of one area can be extrapolated to another. The analysis done in this thesis can also be applied to the OViN dataset of 2016, which at the moment of writing, is expected to be published within a month. Differences between the two years can be investigated.

Future research is not only related to further exploitation of the described information sources, but also to verify the findings in this thesis. Since this thesis provides a theoretical foundation for new features, the practical application of the features should, for example, be tested via a survey or by implementation.

Although car sharing has not yet reached its potential, it is still showing a lot of promise. The identified features show possibilities for car sharing to grow. New technological advancements will help car sharing improve and outgrow its estimated potential. Until the technology becomes available, car sharing organisations can experiment with various features and prepare for the future.

Bibliography

ANWB (2017). *Drie procent filegroei in eerste kwartaal 2017*. URL: https://www.anwb.nl/verkeer/nieuws/nederland/2017/april/filezwaarte-maart (visited on 05/24/2017).

Arbib, James and Tony Seba (2017). *Rethinking Transportation 2020-2030*. Tech. rep.

Baumeister, Roy F et al. (2001). "Bad Is Stronger Than Good". In: *Review of General Psychology* 5.4, pp. 323–370.

Becker, Henrik, Francesco Ciari, and Kay W Axhausen (2017). "Comparing car-sharing schemes in Switzerland: User groups and usage patterns". In: *Transportation Research Part A* 97, pp. 17–29.

Beiraõ, Gabriela and J A Sarsfield Cabral (2007). "Understanding attitudes towards public transport and private car: A qualitative study". In: *Transport Policy* 14, pp. 478–489.

Bendixson, Terence and Martin G Richards (1976). "Witkar: Amsterdam's self-drive hire city car". In: *Transportation* 5, pp. 63–72.

Bert, Julien et al. (2016). *Whats Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales*. Tech. rep. Boston Consulting Group.

Bischoff, Joschka and Michal Maciejewski (2016). "Simulation of city-wide replacement of private cars with autonomous taxis in Berlin". In: *Procedia - Procedia Computer Science* 83, pp. 237–244. ISSN: 1877-0509.

Brownell, Christopher Kirlin (2013). "Shared Autonomous Taxi Networks : An Analysis of Transportation Demand in NJ and a 21 st Century Solution for Congestion". Bachelor Thesis. Princeton University.

Burkhardt, J. E. and A. Millard-Ball (2006). "Who is attracted to carsharing?" In: *Transportation Research Record* 1986, pp. 98–105.

CBS (2015). *Jaarmonitor Wegvoertuigen: Kilometers (2014)*. Tech. rep.

— (2016a). *Jaarmonitor Wegvoertuigen: Aantallen (2015)*. Tech. rep.

— (2016b). *Jaarmonitor Wegvoertuigen: Kilometers (2015)*. Tech. rep.

— (2016c). *Nabijheid voorzieningen; buurtcijfers 2015*. URL: https://www.cbs.nl/nl-nl/maatwerk/2016/16/nabijheid-voorzieningen-buurtcijfers-2015 (visited on 06/26/2017).

— (2016d). *Onderzoek Verplaatsingen in Nederland 2015*. Tech. rep.

— (2017a). *Definitions*. URL: https://www.cbs.nl/en-gb/our-services/methods/definitions?tab=d\#id=degree-of-urbanisation (visited on 05/19/2017).

— (2017b). *Definitions*. URL: https://www.cbs.nl/en-gb/our-services/methods/definitions?tab=u\#id=urban-area (visited on 05/30/2017).

— (2017c). *Definitions*. URL: https://www.cbs.nl/en-gb/our-services/methods/definitions?tab=r\#id=rural-area (visited on 05/30/2017).

— (2017d). *Jaarmonitor Wegvoertuigen: Aantallen (2016)*. Tech. rep.

Cervero, Robert et al. (2002a). "City CarShare: Assessment of Intermediate-Term Travel-Behavior Impacts". University of California at Berkeley.

Cervero, Robert et al. (2002b). "City CarShare: Assessment of Short-Term Travel-Behavior Impacts". University of California at Berkeley.

Cervero, Robert, Aaron Golub, and Brendan Nee (2006). "San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts". University of California at Berkeley.
Chen, T Donna, Kara M Kockelman, and Josiah P Hanna (2016). "Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions". In: *Transportation Research Part A* 94, pp. 243–254.
Cheng, Yung-Hsiang (2010). "Exploring passenger anxiety associated with train travel". In: *Transportation* 37, pp. 875–896.
Chowdhury, Subeh and Avishai Ceder (2013). "The effect of interchange attributes on public-transport users'intention to use routes involving transfers". In: *Psychology and Behavioral Sciences* 2.1, pp. 5–13.
Costain, Cindy, Carolyn Ardron, and Khandker Nurul Habib (2012). "Synopsis of users' behaviour of a carsharing program: A case study in Toronto". In: *Transportation Research Part A* 46, pp. 421–434.
CROW-KpVV (2016). *Autodelen KpVV Dashboard duurzame en slimme mobiliteit*. URL: http://kpvvdashboard-4.blogspot.nl/ (visited on 04/13/2017).
Daziano, Ricardo A, Mauricio Sarrias, and Benjamin Leard (2017). "Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles". In: *Transportation Research Part C* 78, pp. 150–164.
Dictionary, Oxford (2017). *Public transport*. URL: https://en.oxforddictionaries.com/definition/public_transport (visited on 05/23/2017).
Dieten, R J (2015). "Identifying preferences regarding carsharing systems using a stated choice experiment among car users to identify factors of influence". Master Thesis. Eindhoven University of Technology.
Ellaway, Anne et al. (2003). "In the driving seat: psychosocial benefits from private motor vehicle transport compared to public transport". In: *Transportation Research Part F* 6, pp. 217–231.
Fagnant, Daniel, Kara M Kockelman, and P Bransal (2015). "Operations of a Shared Autonomous Vehicle Fleet for the Austin, Texas Market". In: *Transportation Research Record* 2536, pp. 98–106.
Firnkorn, Jörg (2012). "Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany". In: *Transportation Research Part A* 46, pp. 1654–1672.
Fitchard, Kevin (2012). *Ford is ready for the autonomous car. Are drivers?* URL: https://gigaom.com/2012/04/09/ford-is-ready-for-the-autonomous-car-are-drivers/ (visited on 06/07/2017).
Forum, International Transport (2015). *Urban Mobility System Upgrade*. Tech. rep.
Gardner, Benjamin and Charles Abraham (2007). "What drives car use? A grounded theory analysis of commuters' reasons for driving". In: *Transportation Research Part F* 10, pp. 187–200.
Glotz-Richter, Michael (2016). "Reclaim Street Space! – Exploit the European Potential of Car Sharing". In: *Transportation Research Procedia* 14.14, pp. 1296–1304.
Grasset, Vincent and Catherine Morency (2010). "Carsharing: Analyzing the Interaction Between Neighborhood Features and Market Share". In: *Transportation Research Board 89th Annual Meeting*.
Guiver, J W (2007). "Modal talk: Discourse analysis of how people talk about bus and car travel". In: *Transportation Research Part A* 41, pp. 233–248.
Hagman, Olle (2003). "Mobilizing meanings of mobility: car users' constructions of the goods and bads of car use". In: *Transportation Research Part D* 8, pp. 1–9.
Halko, Timo (2012). "Designing public transportation for private car users". Master Thesis. Aalto University.

Harms, Lucas (2008). “Overwegend onderweg”. In: *Social en Cultureel Planbureau*.
Hart, Jorrit van ’t (2012). “Increasing customer satisfaction with public transport”. Master Thesis. TU Delft.
Hiscock, Rosemary et al. (2002). “Means of transport and ontological security: Do cars provide psycho-social benefits to their users?” In: *Transportation Research Part D* 7, pp. 119–135.
Hobrink, Stephan (2014). “Explaining Regional Adoption Differentials in Dutch Car Sharing Markets”. Master Thesis. Universiteit Utrecht.
Jensen, Mette (1999). “Passion and heart in transport — a sociological analysis on transport behaviour”. In: *Transport Policy* 6, pp. 19–33.
Jorritsma, Peter and Kennisinstituut Mobiliteitsbeleid (2015). *Deelautogebruik in Nederland : Omvang, motieven, effecten en potentie*. Tech. rep. Antwerpen: Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk.
Kalra, Nidhi and Susan M Paddock (2016). “Driving to safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability?” In: *Transportation Research Part A* 94, pp. 182–193.
Kanouse, David E. (1984). “Explaining negativity biases in evaluation and choice behavior: Theory and research”. In: *Advances in Consumer Research* 11.1, pp. 703–708.
Katzev, Richard (2003). “Car Sharing: A New Approach to Urban Transportation Problems”. In: *Analyses of Social Issues and Public Policy* 3.1, pp. 65–86.
Kennedy, Brian and Cary Funk (2016). *28% of Americans are ‘strong’ early adopters of technology*. URL: http://www.pewresearch.org/fact-tank/2016/07/12/28-of-americans-are-strong-early-adopters-of-technology/ (visited on 05/19/2017).
Kim, Daejin, Joonho Ko, and Yujin Park (2015). “Factors affecting electric vehicle sharing program participants’ attitudes about car ownership and program participation”. In: *Transportation Research part D* 36, pp. 96–106.
Kim, Jinhee, Soora Rasouli, and Harry Timmermans (2017). “Satisfaction and uncertainty in car-sharing decisions: An integration of hybrid choice and random regret-based models”. In: *Transportation Research Part A* 95, pp. 13–33.
Le Vine, Scott et al. (2014). “A new approach to predict the market and impacts of round-trip and point-to-point carsharing systems: Case study of London”. In: *Transportation Research part D* 32, pp. 218–229.
Lieshout, Marcel van (2016). *Ov-fiets steeds populairder, klanten grijpen vaak mis*. URL: http://www.volkskrant.nl/economie/ov-fiets-steeds-populairder-klanten-grijpen-vaak-mis~a4415129/ (visited on 05/23/2017).
Litman, Todd (2000). “Evaluating Carsharing Benefits”. In: *Transportation Research Record* 1702.1, pp. 31–35.
— (2014). “Autonomous Vehicle Implementation Predictions Implications for Transport Planning”. In: *Traffic Technology International*, pp. 36–42.
Loose, Willi (2010). “The State of European Car-Sharing”. In: *Final Report D 2.4 Work Package 2*.
Martin, Elliot and Susan Shaheen (2011a). “Greenhouse Gas Emission Impacts of Carsharing in North America”. In: *IEEE Transactions on Intelligent Transportation Systems* 12.4.
— (2011b). “The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data”. In: *Energies* 4, pp. 2094–2114.

Meijkamp, Rens (2000). "Changing Consumer Behaviour through Eco-efficient Services An empirical study on Car Sharing in the Netherlands". PhD thesis. Delft University of Technology.

Mercedes (2016). *Future bus pilot*. Tech. rep.

Millard-Ball, Adam et al. (2005). "Car-Sharing: Where and How It Succeeds". In: *Transit Cooperative Research Program*.

Muheim, Peter and E Reinhardt (1999). "Carsharing: the key to combined mobility". In: *World Transport Policy & Practice* 5.3.

Münzel, Karla et al. (2017). "Carsharing Business Models in Germany: Characteristics, Success and Future Prospects". Utrecht University.

Musk, Elon (2016). *Master Plan, Part Deux*. URL: `https://www.tesla.com/blog/master-plan-part-deux` (visited on 05/23/2017).

NHTSA (2013). *Preliminary Statement of Policy Concerning Automated Vehicles*. Tech. rep. National Highway Traffic Safety Administration.

NHTSA and USDOT (2015). *Traffic safety facts: Crash stats*. Tech. rep. Washington DC: National Highway Traffic Safety Administration, U.S. Department of Transportation.

Nijland, Hans, Jordy van Meerkerk, and Anco Hoen (2015). *Effecten van autodelen op mobiliteit en CO2-uitstoot*. Tech. rep. Planbureau voor de Leefomgeving.

NS (2017). *Energy*. URL: `http://www.ns.nl/en/about-ns/energy` (visited on 05/23/2017).

OECD (2017). "ITF Transport Outlook 2017". In:

Parkan, Celik (2002). "Measuring the operational performance of a public transit company". In: *International Journal of Operations & Production Management* 22.6, pp. 693–720.

Redman, Lauren et al. (2013). "Quality attributes of public transport that attract car users: A research review". In: *Transport Policy* 25, pp. 119–127.

Rietveld, Piet (2005). "Six reasons why supply oriented indicators systematically overestimate service quality in public transport". In: *Transport Reviews* 25.April, pp. 319–328.

Rijksoverheid (2015). *Autodelen: naar 100.000 deelauto's in 2018*. Tech. rep.

— (2016a). *Dutch public transport switches to 100 percent emissions-free buses*. URL: `https://www.government.nl/latest/news/2016/04/15/dutch-public-transport-switches-to-100-percent-emissions-free-buses` (visited on 05/23/2017).

— (2016b). *Overstappen naar 2040: Flexibel en slim OV*. Tech. rep.

— (2017). *Wat zijn de regels voor fietsverlichting en reflectie op een fiets?* URL: `https://www.rijksoverheid.nl/documenten/vragen-en-antwoorden/wat-zijn-de-regels-voor-fietsverlichting-en-reflectie-op-een-fiets` (visited on 05/08/2017).

Schaefers, Tobias (2013). "Exploring carsharing usage motives: A hierarchical means-end chain analysis". In: *Transportation Research Part A* 47, pp. 69–77.

SFMTA (2017). *On-Street Car Sharing Pilot Program*. Tech. rep.

Shaheen, Susan and Nelson Chan (2015). *Mobility and the sharing economy: Impacts synopsis*. Tech. rep. University of California, Berkeley: Transportation sustainability research center.

Shaheen, Susan, Daniel Sperling, and Conrad Wagner (1998). "Carsharing in Europe and North America: Past, Present, and Future". In: *Transportation Quarterly* 52.3, pp. 35–52.

Shaheen, Susan A and Adam P Cohen (2007). "Worldwide carsharing growth: An international comparison". In: *Transportation Research Record: Journal of the Transportation Research Board* 1992.1, pp. 81–89.

Shaheen, Susan A, Mark A Mallery, and Karla J Kingsley (2012). "Personal vehicle sharing services in North America". In: *Research in Transportation Business & Management* 3, pp. 71–81.

Shoup, Donald C (2006). "Cruising for parking". In: *Transport Policy* 13, pp. 479–486.

Steininger, Karl, Caroline Vogl, and Ralph Zettl (1996). "Car-sharing organizations The size of the market segment and revealed change in mobility behavior". In: *Transport Policy* 3.4, pp. 177–185.

Stemler, Steve (2001). "An Overview of Content Analysis". In: *Practical Assessment, Research & Evaluation* 7.17.

Stillwater, Tai, Patricia Mokhtarian, and Susan Shaheen (2009). "Carsharing and the Built Environment". In: *Transportation Research Record: Journal of the Transportation Research Board* 2110, pp. 27–34.

Suiker, Stephan and Jos van den Elshout (2013). *Effectmeting introductie Car2Go in Amsterdam*. Tech. rep. Nationaal verkeerskundecongres.

Terrien, Clara et al. (2016). "Good practices for advancing urban mobility innovation: A case study of one-way carsharing". In: *Transportation Business & Management* 20, pp. 20–32.

Tertoolen, Gerard, Dik Van Kreveld, and Ben Verstraten (1998). "Psychological resistance against attempts to reduce private car use". In: *Transportation Research Part A: Policy and Practice* 32.3, pp. 171–181.

TNS Nipo (2014). *Monitor Autodelen 2014*. Tech. rep.

Tubantia (2017). *Gemeente Enschede zet in op elektrische flexauto's*. URL: http://www.tubantia.nl/enschede/gemeente-enschede-zet-in-op-elektrische-flexauto-s~a6dc7599/ (visited on 05/29/2017).

UITP (2017). "Autonomous Vehicles: A potential game changer for urban mobility". In:

Van Hagen, Mark (2009). "How to meet the needs of train passengers? A successful customer segmentation model for public transport". In: *European Transport Congress*. Noordwijkerhout, the Netherlands.

Vliet, Hans Van (2007). *Software Engineering: Principles and Practice*. Third edit. Wiley, p. 59. ISBN: 0470031468.

Wong, John L. and Jagdish N. Sheth (1985). "Explaining Intention-Behavior Discrepancy–A Paradigm". In: *Advances in Consumer Research* 12, pp. 378–384.

Yadron, Danny and Dan Tynan (2016). *Tesla driver dies in first fatal crash while using autopilot mode*. URL: https://www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk (visited on 06/07/2017).

Yap, Menno D., Gonçalo Correia, and Bart van Arem (2016). "Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips". In: *Transportation Research Part A* 94, pp. 1–16.

Zelfsturing.it (2017). *1 op de 3 Nederlanders wil een zelfrijdende auto*. URL: http://zelfsturing.it/1-op-de-3-nederlanders-wil-een-zelfrijdende-auto/ (visited on 06/07/2017).

Appendix A

Online Review Analysis

A.1 Greenwheels

Search queries

(Greenwheels) + review, forum, ervaring, beoordeling, gebruik

Review websites

Review 1-3	Tweakers.net
Review 4	Tweakers.net
Review 5-7	Radar
Review 8-9	Viva
Review 10	Kidseropuit
Review 11	Eigenwijs Blij

A.2 Car2go

Search queries

(Car2go) + review, forum, ervaring, beoordeling, gebruik

Review websites

Review 1	Yelp
Review 2	Google Play Store
Review 3	Business Insider
Review 4	AartJan

A.3 OV-fiets

Search queries

(OV-fiets) + review, forum, ervaring, beoordeling, gebruik, proef, onderzoek

Review websites

Review 1-6	NS forum
Review 7	NS forum
Review 8-9	Yelp
Review 11	Rover
Review 12	Tweakers
Review 13	Viva
Review 14	Universiteit Utrecht

Company	Source	Total #	Current #	Content type	Format	Primary audience	Experience	Main topic	Notes/features							
Greenwheels	Tweakers	1	1	Forum startpost	Text	Forum visitors		Experience	No PT alternative available	High cost						
		2	2	Forum post #12	Text	Forum visitors		Experience	Pay for not moving	Small cars	Affordable with little usage					
		3	3	Forum post #16	Text	Forum visitors		Experience	Recent growth	Only useful when close by	Less fixed costs	No maintenance				
	Tweakers	4	1	Forum post #19	Text	Forum visitors		Experience	Only useful when close by	High cost	Clean	Full of gas	High hour rate			
	Radar	5	1	Forum post #1	Text	Forum visitors		Experience	Only useful when close by	Small cars	Good price/quality					
		6	2	Forum post #3	Text	Forum visitors		Experience	Check for damage	High cost						
		7	3	Forum post #5	Text	Forum visitors		Experience	High cost	Use for short trips	Bad customer service					
	Viva	8	1	Forum post #2	Text	Forum visitors		Experience	Only useful when close by	Pay for not moving	Use for short trips	Good customer service	No hassle with inspections and repairs	Small cars		
		9	2	Forum post #6	Text	Forum visitors		Experience	Only useful when close by	Small cars	High cost					
	Kidseropuit.nl	10	1	Blog/Review	Text + images	Website visitors		Experience	Use ov card	Reservation simple	Small cars	Attractive color				
	Eigenwijs Blij	11	1	BlogReview	Text	Website visitors		Experience	Only useful when close by	Use ov card	Green	Cheaper than owning car	No hassle with inspections and repairs	Small cars	Use for short trips	

Company	Source	Total #	Current #	Content type	Format	Primary audience	Experience	Main topic	Notes/features							
Car2go	Yelp	1	1	Review	Text	Yelp visitors		Experience	Faster	Comfortable	Park everywhere	No call service	Costs afterwards	Damage check		
	Google Play store	2	1	Review	Text	(potential) app users		App reviews	Occupied chargers	No availability	Less cars in centre at night					
	Business Insider	3	1	Review	Text + image	BI readers		Experience	Affordable	Parking fees included	Free minutes when parked at charging station	Limited parking area	Car range in cold weather			
	AartJan	4	1	Blog	Text+ images	Website visitors		Experience	Parking free	Park everywhere	Cheap	PT alternative	Smartphone usage	Good quality	Bad manual	Cold

Company	Source	Total #	Current #	Content type	Format	Primary audience	Experience	Main topic	Notes/features							
OV-fiets	NS forum	1	1	Forum startpost	Text	Forum users		Quality of bikes	Standard bike	No luxury	No handbrakes	No gears	Old bikes	Broken bikes		
		2	2	Forum reaction #2	Text	Forum users		Quality of bikes	Broken bikes	Selfservice	Bike pick procedure order					
		3	3	Forum reaction #3	Text	Forum users		Procedure	No standard procedure	Standardisation						
		4	4	Forum reaction #10	Text	Forum users		Quality of bikes	Broken lights	Pay to reserve	Bike pick procedure order	Inform about defects				
		5	5	Forum reaction #11	Text	Forum users		Broken bike	Broken bikes	No bus alternative						
		6	6	Forum reaction #13	Text	Forum users		Broken bike	Broken bikes	No repair on site						
	NS forum	7	1	Forum startpost	Text	Forum users		Renting issues	No explanation on site	Subscription required						
	Yelp	8	1	Review	Text	Yelp visitors		A great service	Fast	Good price						
		9	2	Review	Text	Yelp visitors		Useful and cheap	Good price	Return to pickup location						
		10	3	Review	Text	Yelp visitors		Useful and cheap	Good price	Lots of locations						
	Rover	11	1	Blog	Text	Rover visitors		Great success	Safe	Fast	Bike pick procedure order	Environmental friendly	No option to reserve	Good price		
	Tweakers	12	1	Forum reaction #8	Text	Forum users		Mixed review	No bike available	Broken bikes	No compensation for non-availability	No explanation on site	Slow servicedesk	Good price		
	Viva	13	1	Forum reaction #5	Text	Forum users		Good experiences	Broken lights	Good availability	Dependent on opening hours					
	Universiteit Utrecht	14	1	News item	Text + image	University students + staff		PT alternative	Bike preferred over bus	Good price						

FIGURE A.1: Online review analysis overview