Erasmus University Rotterdam
Department of Applied Economics

The effects of and the possibilities for offering car sharing services

A quantitative spatial market research into the explanatory factors for the use of car sharing

Master thesis Economics & Business,
specialization Urban, Port and Transport Economics

Utrecht, June 27, 2013

Author:

Johannes Haverkate
EUR-student number: 305348

Supervisor:

Drs Giuliano Mingardo

Preface

After a period of almost seven years, my student life has come to an end. It was a very nice period for me in which I have learned a lot and in which I have met many people. This thesis for the master Urban, Port and Transport Economics at the Erasmus University Rotterdam marks the end of this time. It is about a relatively new concept in the world of mobility, namely car sharing. The research discusses in detail many issues regarding sustainable mobility and car sharing and shows based on a lot of quantitative data and calculations which factors affect the demand for car sharing. I have also combined the writing of this thesis with an internship at the 'Kennisplatform voor Verkeer en Vervoer' in my hometown Utrecht. It was very useful and nice for me to work in a professional organization with a lot of knowledge regarding the topic of car sharing.

However, there were also some difficulties. Especially, the fact that I also had to write another thesis for the master Urban and Regional Planning makes it sometimes complicated to pay attention to this research. After handing in the other thesis, it was easier to spend time to this thesis and to come to an end product.

I also would like to take the opportunity to thank some people. First of all, I would like to thank my supervisor at the Erasmus University Giuliano Mingardo, because of his helpful advices and tips and the time he has put in my counseling. My personal supervisor at KpVV, Friso Metz, deserves my thanks for guiding me during the writing process and for his advices from daily practice regarding sustainable mobility. My thanks go also to my former colleagues of KpVV for providing me with data, for answering some important questions and for the nice moments and conversations in the workplace. Furthermore, I would like to thank the teachers and students of the master Urban, Port and Transport Economics for the nice and useful lectures and discussions in which I learned a lot about geographical economical issues. Finally, my thanks go to my family, friends and housemates for motivating me at the right time and for the nice moments of relaxation.

Johannes Haverkate

Utrecht, June 2013

Summary

This master thesis presents a spatial market analysis about the explanatory factors for the demand to traditional car sharing services in residential areas. The principle of car sharing is as follows: a provider of car sharing services allocates a vehicle to a neighborhood or city. The municipality often reserves parking space for the shared car and people who register themselves at the car sharing services company are able to use the car at any time they would like. Customers of a car sharing company only pay for using the car. Costs with respect to purchase, maintenance and depreciation are for the provider.

According the theory, offering car sharing services probably has some advantages with respect to sustainable mobility, such as a complementary relation with the use of public transport and bikes, a reduction in the demand for parking space and car mileages for former car owners, a travel solution for people which do not possess a car and increasing awareness about mobility behavior. Some disadvantages are also present, such as an increasing car use of people which did not drive before and also the current benefits with respect to the solution of traffic and environmental problems are very low, because there are very few customers. However, car sharing is a relatively new concept and is continuously growing in the Netherlands and that's why it may have social benefits with respect to sustainable mobility in the long term and may be an integral part of a total sustainable mobility package of public transport (long distances), cycling (short distances) and car sharing (tangential and regional distances).

According the theory, there exist many interactions between transport and land use and that's why some hypotheses have been conducted in order to test some relationships between spatial indicators and the use of car sharing services. Especially, the use of cycling and public transport and density seems to have a positive impact on the availability of car sharing services

On the other hand, also some characteristics with respect to customers probably have a large explanatory power, according the theory. The presence of higher-educated people, the presence of people between the ages of 25 and 45 years and the disposable income seem to have a positive impact on the availability of car sharing services, while car ownership and average household size have a negative relationship with the use of car sharing services, according the theory.

In order to test the hypotheses, the impact of a lot of indicators have been empirically tested by using data from 100 municipalities which is almost a quart of the total number of municipalities in the Netherlands. The explanatory indicators have been tested in different compositions and the outcomes have extensively been analyzed.

According the outcomes of the models, almost each indicator has a single impact in the way as expected according the theory. However, if they have been tested commonly, the impact of some indicators change. Only the expected relationships between the presence of higher-educated people, average household size, car ownership and density on the one hand and the use of car sharing services on the other hand hold. Although there is some evidence for a positive relationship between cycling, public transport, income and the presence of people between the ages of 25 and 45 years on the one hand and the availability of shared cars on

the other hand, full evidence is lacking, because indicators for these factors have impact in models with only customer or spatial characteristics, but do not have much explanatory power in models with all relevant factors as explanatory variables. The results for the hypotheses have been summarized in table 1.

Table 1: Hypotheses and outcomes

Hypothesis	Result
1: There is a positive relationship between the accessibility provided by public transport and the use of car sharing services	Rejected
2: There is a positive relationship between the share of cycling in the modal split and the use of car sharing services	Rejected
3: There is a positive relationship between density and the use of car sharing services	Accepted
4: There is a positive relationship between the presence of people between the ages of 25 and 44 years old and the use of car sharing services	Rejected
5: There is a positive relationship between the level of education and the use of car sharing services	Accepted
6: There is a negative relationship between household size and the use of car sharing services	Accepted
7: There is a negative relationship between car ownership and the use of car sharing services	Accepted
8: There is a positive relationship between the level of income and the use of car sharing services	Rejected

Based on these outcomes, it can be concluded that urban neighborhoods with a high population density, a high presence of people with college and university degrees, a lot of smaller households, low degrees of car ownership and probably also a high presence of people between the ages of 25 and 45 years are potentially most favorable for offering car sharing services.

Table of contents

1. Introduction

1.1. Car sharing: an introduction

Efficient transportation systems and mobility are essential for the economy of European cities and for the wealth of their citizens (European Commission, 2009). However, mobility has also some negative externalities, such as congestion, noise production, accidents and pollution (Handy, 2002). These problems with respect to mobility could lead to a lower level of accessibility and livability and these problems are strengthened because of ever increasing mobility and car use. This unsustainable situation is now widely recognized. That's why the European Union takes measures and sets guidelines to promote sustainable mobility (European Commission, 2007; European Commission, 2009).

A relatively new concept with respect to sustainable mobility is car sharing. The principle of the traditional way of car sharing is as follows: a provider of car sharing services allocates a vehicle to a neighborhood or city. The municipality often reserves parking space for the shared car and people who register themselves are able to use the car at any time they want. People who are members of a car sharing provider pay only for using the car and not for purchase, maintenance and depreciation.

Traditional car sharing services can be positioned in three ways. They can be offered at companies or business locations in order to reduce the dependence of employees of their private cars. Secondly, car sharing services can be offered at public transport nodes in order to facilitate the last part of a customer's trip. Finally, they can be offered at residential locations close to customers in order to facilitate direct movements from origin to destination. This thesis will focus on the last type of offering car sharing. Furthermore, there also new forms of car sharing, such as peer to peer and one way car sharing, but they have not been examined, because they are less demand driven compared to the traditional way of car sharing. In the rest of this study, the terms 'car sharing' and 'car sharing services' refer to the traditional way of car sharing, unless explicitly stated otherwise.

KpVV (2009) states that that car sharing customers have some common characteristics. They are on average 40 years old, their households are smaller and they have high average incomes. Moreover, they work often at home or do not need a car for commuting and they drive less than 10,000 km a year. Moreover, according to KpVV (2009) and Meijkamp (2000), members of car sharing organizations make more often use of other sustainable modes such as public transport and cycling and they are more conscious about their mobility behavior and adoption of car sharing by former car owners may lead to a reduction in car mileage and the demand for parking space.

These possible positive effects of using car sharing services on using sustainable modes give rise to investigate which kind of residential areas are actually suitable for offering car sharing services.

1.2. Research design

1.2.1. Research question and sub questions

Based on literature and theory about sustainable mobility and car sharing services, the next research question can be derived:

''Which kind of residential areas are most suitable for offering car sharing services?''

In order to answer the research question, the study will be structured by answering some sub questions.

1. What are the advantages and disadvantages with respect to sustainable mobility to offer car sharing at residential locations?
2. What is the impact of spatial characteristics on the availability of car sharing services at residential locations?
3. What are the main characteristics of (potential) car sharing customers?
4. Based on characteristics of residents and living area, which residential areas in the municipality of Rotterdam are suitable for offering car sharing services?

1.2.2. Relevance

Examining the explanatory factors for the use of car sharing services in residential areas is relevant from both a societal and scientific perspective. It is relevant to study a strengthening of the position of car sharing in residential areas from a societal perspective, because it may contribute to a more sustainable travel behavior of customers and positive complementary effects for cycling and public transport. Moreover, a better insight in the explanatory factors may help to target new customers and residential areas.

Examining the positioning of car sharing in residential locations is relevant from a scientific perspective, because a gap can be identified in the existing literature about car sharing. Little scientific research has been implemented with respect to car sharing in general in the Netherlands. Existing studies are mainly focused on the positioning of car sharing in older city neighborhoods in central city areas.

1.2.3. Research methods

The research design is following a deductive approach. Based on existing knowledge and theoretical considerations with respect to the subject, hypotheses will be formulated and tested (Bryman, 2008). This is an important characteristic of quantitative research. According Bryman (2008), quantitative research is a research strategy based on testing theories based on numbers and values.

In order to answer the research question and the sub questions, both a theoretical and empirical research will be implemented. In the theoretical part, first the advantages and disadvantages of offering car sharing services with respect to sustainable mobility behavior will be discussed. Subsequently, some indicators with respect to customers and living area which may predict the use of car sharing services will be derived from existing literature and will be tested by hypotheses.

In the empirical part, the hypotheses have been tested by using multiple regression analyses which test the impact of the indicators in a quantitative way. The results will be applied to the municipality of Rotterdam in order to identify the neighborhoods with the highest potential for offering car sharing services.

Data

For empirically testing the relationship between characteristics of customers and living area on the one hand and the position of car sharing services on the other hand, a large sample with data about hundred municipalities have been used. Data from KpVV (2013) about the availability of car sharing services and from CBS StatLine (2013), Nationale Bereikbaarheidskaart (2013) and KNIG (2013) about customer and spatial characteristics have been obtained.

Validity

It is important to fulfill the criteria of reliability and validity. The criterion of reliability can be fulfilled by describing all methodological steps that have been taken during the research. In this way, a study becomes reproducible for other scientists (Bryman, 2008). Four types of validity exist, measurement validity, internal validity, external validity and ecological validity. According Bryman (2008), internal and external validity are most important. Internal validity means to which extent the conclusion that represents a relation between two variables holds water. By implementing scientifically sound methods, such as multiple regression analyses which estimate the significance of relationships between two variables, the criterion of internal validity will be satisfied.

External validity has to deal with the extent in which the findings can be generalized. By using a sample which includes data about hundred Dutch municipalities, a very high external validity has been generated, because approximately a quarter of all Dutch municipalities has been included in the sample.

1.2.4. Chapter structuring

This master thesis consists of both a theoretical and an empirical part. Chapter 2 gives an introduction about sustainable mobility, mobility problems, the advantages of offering car sharing, the interaction between transport and space, customer characteristics and finally the hypotheses have been derived from literature. Subsequently, chapter 3 describes the data and discusses the empirical methods that have been used. In chapter 4, the results have been presented. Chapter 5 discusses these results and hypotheses have been assessed in this chapter. In chapter 6, the main findings will be applied to the municipality of Rotterdam. Finally, chapter 7 presents the conclusions, discusses some limitations and gives a number of recommendations.

2. Theory

This chapter is about the relation between car sharing services and sustainable mobility and about some determinants of the use of car sharing services. First, section 2.1 presents the concept of sustainable mobility. Section 2.2 discusses actual problems with respect to car mobility. In section 2.3, car sharing has been introduced and its relevance with respect to sustainable mobility will be discussed. Section 2.4 is about the relation between car sharing services on the one hand and density and other sustainable modes of transport on the other hand. In section 2.5, some general characteristics of car sharing customers have been examined, because these characteristics may determine which kind of people are potential car sharing customers. Finally, in section 2.6 some hypotheses are deducted from the literature in this chapter.

2.1. Sustainable mobility

Efficient transportation systems and mobility are essential for the economy of European cities and for the wealth of their citizens (European Commission, 2009). However, mobility produces also a number of negative externalities. Almost all European cities face the same kind of mobility problems. Especially during rush hours, citizens in urban regions have to deal with congestion and longer journey times which can lead to great losses for business. In addition, traffic in European cities is responsible for the emission of 40 percent of the total amount of carbon dioxide and 70 percent of other harmful substances and causes a lot of noise. Moreover, mobility also implies a high number of accidents (European Commission, 2007).

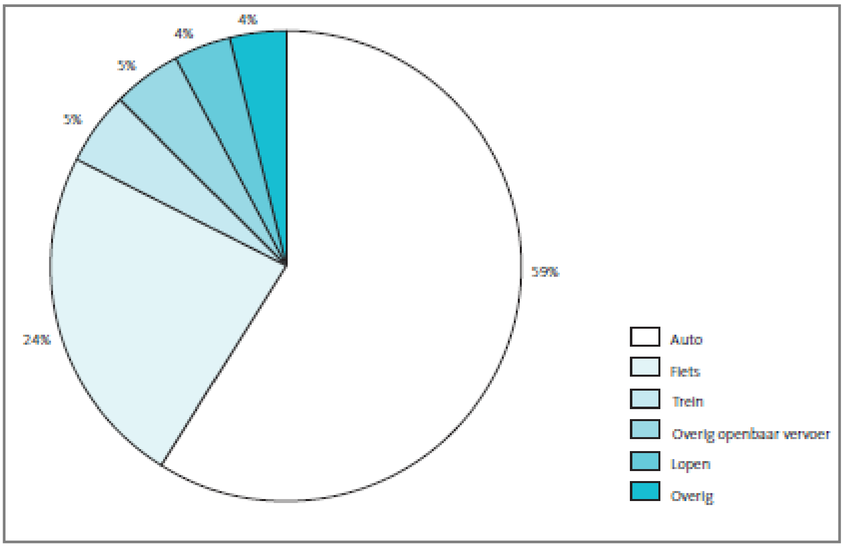
These problems with respect to mobility could lead to a lower level of accessibility and livability and these problems are strengthened because of increasing mobility and car use. This unsustainable situation is now widely recognized. That's why the European Union takes measures and sets guidelines to promote sustainable mobility (European Commission, 2007; European Commission, 2009). Local, regional and national governments are encouraged to implement sustainable urban mobility plans. Sustainability will be defined as *''meeting the needs of the present without compromising the ability of future generations to meet their own needs''* (WCED, 1987, p.43). Mobility plans are sustainable if they improve accessibility without creating negative externalities in societal, environmental and economic well-being that more than offset the benefits of improvements with respect to accessibility (WBSCD, 2001). Concrete actions which are part of a sustainable mobility approach are encouraging modal shift, reducing trip lengths, reducing the need for trips and increasing the efficiency of transportation systems (Banister, 2008).

2.2. Mobility problems

Car mobility is responsible for the largest part of the problems with respect to sustainability in Europe and North-America. The growth in vehicle travel kilometers has continuously increased during last decades and has been supported by investments in roads. But the growth in vehicle travel kilometers exceeds by far the growth in kilometers of roads constructed. For example, total number of vehicle travel kilometers in the U.S. has increased by 724% between 1941 and 2000 while total kilometers of roads has grown by 145% during the same period. (Handy, 2002). Consequently, a lot of kilometers must be constructed to accommodate the growth in vehicle kilometers and to solve the congestion problems which is impossible due to the enormous costs and the lack of space in metropolitan areas. Moreover, increasing car mobility leads to problems with respect to air quality and noise. There are two strategies to solve mobility problems in a more sustainable way. The first strategy is a technological approach which focuses on reducing the negative externalities of car mobility by using cleaner fuels and using more intelligent traffic management systems. However, this strategy deals with a lot of uncertainties and technological innovations are often expensive (May & Marsden, 2010). That's why many scientists also advocate a second strategy to solve mobility problems which includes the reduction of car mobility together with increasing accessibility by investing in the quality of transit, walking and cycling and bringing activities closer to home (Banister, 2008; Handy, 2002; Meyer & Miller, 2001).

However, for being successful in implementing these measures, a break in the mobility behavior of consumers is needed. The car is by far the most popular mode of transport in Europe and North-America. Also in the Netherlands, the car is the most important mode of transport. This is illustrated by CBS figures about the choice of the main mode of transport to work. The car is by far the most dominant mode with a modal share of approximately 59 percent, cycling has a modal share of 24 percent, public transport has a share of 10 percent and walking 4 percent (CBS, 2012).

Figure 1: Modal split with respect to the total number of trips to work in the Netherlands in 2010



Source: CBS, 2012, p.8

Owning and using a car gives people an immense flexibility with respect to their movements. Car-drivers can move to any place at any time in an easy and comfortable way. Other reasons for the dominance of car use are out of habit, the status that cars give to their owners, the freedom that they provide and last but not least the lack of alternatives (Jeekel, 2011; Urry, 2004). Many locations are only accessible by car and public transport is not available during specific times. Moreover, for implementing activities which require a lot of luggage, the car is the only real alternative. Many people are in a certain way dependent of their cars, because otherwise they cannot live the life that they would like (Jeekel, 2011).

The above paragraphs outline a dilemma regarding car mobility. On the one hand, facilitating car mobility is unsustainable, because of its negative consequences for environment. On the other hand, people are often dependent of their cars and mobility is an essential condition for economic development (Bertolini, 2010). Without their cars, many people cannot implement the activities they would like. The question which arises, is how to reduce the negative consequences of car use without limiting the freedom and flexibility of people.

2.3. Car sharing

Many initiatives have been carried out in the Netherlands to stimulate the use of sustainable transport modes, but they have not brought about major changes in mobility behavior and modal split at the macro level and the total number of kilometers travelled by car has grown continuously during last decades (CBS StatLine, 2013; Jeekel, 2011).

A relatively new initiative with respect to sustainable mobility is the concept of car sharing. Car sharing can be defined as *'the repetitive and sequential joint use of motor vehicles pursuant to an agreement between natural persons and a provider or between natural persons from more than one household'* (KpVV, 2009, p.5). The principle of the traditional way of car sharing is as follows: a provider of car sharing services allocates a vehicle to a neighborhood or city. The municipality often reserves parking space for the shared car and people who register themselves are able to use the car at any time they would like. People who are members of a car sharing provider pay only for using the car and not for purchase, maintenance and depreciation. Car sharing services may fill the gap between private car and public transport and that's why it deserves attention.

Positioning of car sharing

Traditional car sharing can be positioned in three different ways. First, car sharing services can be offered to customers at residential locations in order to facilitate entire trips from origin to destination. In this case, shared cars are stationed near (potential) customers. In the Netherlands, car sharing originally has been started in this form during the 1990s. Shared cars were allocated to older city areas with high densities and parking problems. People who lived in these areas used car sharing services mainly for private trips to family and friends. They used public transport and the bike for making home-work trips (Ministerie van Verkeer en Waterstaat, 2003). Currently, a significant part of car sharing services in the Netherlands has been positioned in older neighborhoods with higher densities. However, car sharing services are also offered in municipalities with lower densities without parking problems. For example, smaller municipalities like Bunnik, Culemborg, Wageningen, Houten and Zutphen have a ranking in the top 10 highest numbers of shared cars compared to the number of inhabitants (KpVV, 2013).

Secondly, car sharing services could also be used in combination with other modes, such as train and metro. Car sharing services may be offered for the last part of the trip from a public transport node to the final destination. In this case, shared cars are stationed close to public transport nodes. This form of car sharing has been introduced in the Netherlands at the beginning of this century. Car sharing services provider Greenwheels and railway operator NS have started a partnership and nowadays shared cars are available at approximately 90 railway stations across the Netherlands (Greenwheels, 2012).

Finally, car sharing services could be offered at companies and business locations. Employees may use shared cars for business trips and are not dependent of their private cars for making business trips in this way. They have the possibility to travel by bike or public transport to work (KpVV, 2009).

This study focus mainly on car sharing offered at residential locations.

Advantages and disadvantages
Car sharing is more sustainable for society than private car ownership, for a couple of reasons. First of all, allocating a shared car to a neighborhood leads to a reduction in the demand for parking space (KpVV, 2009; Shaheen *et al.*, 1998). If two or more people give up their own cars, because of the introduction of car sharing services, more parking space will be available. In general it can be stated that on balance more space will be available after introducing car sharing services. In Amsterdam, for example, each shared car saves 3,14 private cars. In cities with higher car ownership rates, such as Wageningen and Houten, each shared car replaces 5 to 6 private cars.

Another advantage of car sharing is that members who owned a private car before make more use public transport and cycling (KpVV, 2009; Meijkamp, 2000; Nanninga & Eerdmans, 2006). Subscribers of car sharing services will be more aware of their mobility behavior, because they pay for use and not for possessing. Instead of always using the private car, subscribers make a trade-off each time between different mobility alternatives.

Thirdly, car sharing organizations are offering mobility to people without a car, such as young people, elderly and people with lower incomes. Car sharing may also lead to a reduction in mileage, because some people give up their private cars or they probably would buy a car if they did not have access to car sharing services (KpVV, 2009; Meijkamp, 2000; Nanninga & Eerdmans, 2006). This group of customers drive significantly fewer miles after the introduction of car sharing services.

However in contrast to the customer group of former car owners, people who previously did not own a private car drive more often after the introduction of car sharing services. Instead of taking public transport or the bike, they use less sustainable shared cars for some trips. However, using car sharing services may prevent the purchase of a private car.

But according to Meijkamp (2000) and Nanninga & Eerdmans (2006), introduction of car sharing services in residential areas ultimately leads to a net decrease in car mileages. Although, the customer group of former car owners is twice as small as the group who previously did not own a car (adopters), the reduction in car mileage is much larger than the increasing mileage of people who did not own a car. The net reduction in car mileage immediately leads to positive environmental effects, such as less emission of harmful substances. Moreover, shared cars are often cleaner and less polluting, newer and more economical compared to private cars (KpVV, 2013). In the table below advantages and disadvantages are summarized per customer type.

Table 2: Advantages and disadvantages of adopting car sharing services

	Advantages	Disadvantages
Former car owner	▪ Reduction in demand for parking space ▪ Awareness of mobility behavior ▪ More use of public transport and bike ▪ Decrease in car mileages ▪ Shared cars often cleaner	
Adopter	▪ Awareness of mobility behavior ▪ Offering mobility to people without a car ▪ Preventing purchase of a private car	▪ Need for additional parking space ▪ Less use of public transport and bike ▪ Increase in car mileages after adopting

Source: Own interpretation

In April 2011, 2100 shared cars were stationed throughout the Netherlands, an increase of 131% compared to 2006. Car sharing is by far most popular in Amsterdam, almost half of all shared cars is stationed within the borders of the Dutch capital. Other cities with a high number of shared cars can be characterized as moderate or strong urban (KpVV, 2013). However, the number of shared cars is nil compared to the total fleet of almost 8 million private cars in the Netherlands (CBS StatLine, 2013).

2.4. Availability of public transport, densities and car sharing

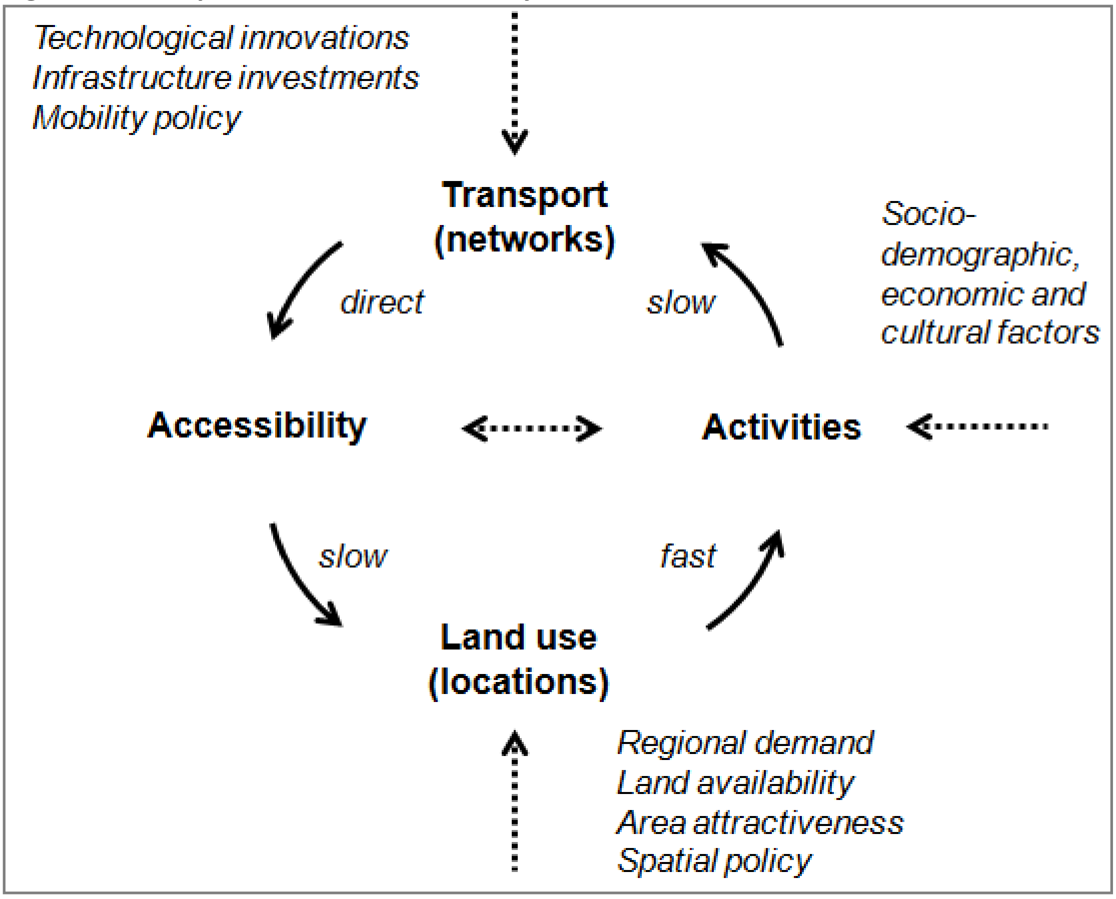
The Dutch ministry of transport has stated some years ago that the level of car sharing in the Netherlands could be substantially higher, if car sharing would be integrated with other modes, such as public transport and if it would be part of an integral transport policy (Ministerie van Verkeer en Waterstaat, 2003). Moreover, possible complementary effects between car sharing and public transport exist. That's why it is interesting to examine the impact of public transport at residential locations on the position of car sharing services.

2.4.1. Interaction between transport and land use

According Meyer & Miller (2001), the relationship between transport and land use is essential for understanding the transportation system. Land use characteristics explain for a large part trip patterns and modal distributions. Regional travel patterns have largely been influenced by land use patterns. The reverse is also true, accessibility provided by the transportation system may affect land use patterns (Meyer & Miller, 2001).

One of the most important models which gives insight in the links between spatial structures and transport is the 'land use transport feedback cycle' (Bertolini, 2010; Wegener & Fürst, 1999). The reasoning behind the circle is as follows (see figure 2). The spatial distribution of land use determines the locations of human activities, such as living, working, shopping and leisure. Because locations of human activities are segregated in space, trips are needed to overcome the distances between the locations and developments in the transportation system respond to the trip patterns of people. The transportation system determines the level of accessibility of different locations and the level of accessibility explains what locations are suitable for the establishment of activities. Then the whole process starts again from the beginning. The cycle is an open model, because also other variables have impact on the components included in the cycle. The transportation system is not only influenced by activities, but also by technological innovations, investments in infrastructure and mobility policy. The distribution of land use is also explained by the attractiveness of an area in general, the demand for land, the availability of land and spatial policy. Human activities are partly explained by demographic, economic and cultural factors. Moreover, activities may directly have an impact on the level of accessibility without first changing the transportation system. Conversely, accessibility may directly determine patterns in activity without changing the land use (Bertolini, 2010).

Figure 2: Transport land use feedback cycle



Source: Own interpretation based on Bertolini, 2010 and Wegener & Fürst, 1999

Response times vary greatly between the different variables. A change in the spatial distribution of land use leads quickly to a change in activities on a location, while changes in accessibility and activities result slowly in a change of respectively land use patterns and the transportation system. The accessibility level responds immediately to changes in the transportation system (Bertolini, 2010).

The transport land use feedback cycle gives insight in reinforcing and weakening effects of interventions in the distribution of land use and the transport system. Building in higher densities and mixed use of areas around public transport nodes supports the implementation of activities close to home and generates more support for public transport. Investments in public transportation and cycling networks will lead to better accessibility of an area and make the area again more attractive for development (Bertolini, 2010). The recognized interaction of transport and land use has led to transit-oriented development policy in many cities. This policy encourages mixed use and building in higher densities around public transport nodes . Vice versa, developing in low density structures and separate use will lead to more car use, because of increasing distances and spatial distribution of activities.

Another theory about the interaction between mobility and space comes from Storper & Manville (2006) and has to deal with preferences of people. According to them, many goods are supplied in bundles, because of path dependency. City life and slow modes form a bundle with each other, because cities are unpleasant places to drive by car and spatial structures adapt very slowly. On the other hand, space and driving form also a bundle, because it is not possible to have access to different kinds of amenities in a low density suburban environment without a car. If someone lives in a low density living area, but dislikes car use, he still use the car, because of the lack of alternatives, according the theory of Storper and Manville (2006). In this case, low density living is his revealed preference, but disliking car use is a latent and second-order preference. However, because of technological innovations, rises in income and new developments, preferences for land and space may slightly be unbundled and revealed preferences may change as a result of it (Storper & Manville, 2006). For example, a car-based living style is now also possible in cities with high densities, because of the construction of parking garages and car roads. However, a car-based living style is still not ideal in cities, because of congestion and restrictions in parking and people's income.

It will be clear that higher density areas support the use of public transport, while lower density areas stimulate the use of private cars. However according Storper & Manville (2006), preferences for modes of transport and space are slowly unbundled from each other and also the offering of car sharing services may play a role in this process. It might be that car sharing services could be an alternative for the private car in lower density areas where public transport is lacking, but it may also be the case that car sharing will act as a complement to public transport in higher density areas. This will be studied in the next sections.

2.4.2. Complementary and substitution effects

Adopting car sharing services may affect the use of public transport by customers. There are three potential effects. Adopting car sharing services may lead to more use of bus, metro and train which makes it complementary to public transport. Adopting car sharing services may also replace trips by bus and train which makes it a substitute for public transport. Finally, it is also possible that adopting car sharing services does not affect the use of public transport.

According Transportation Research Board (2005), car sharing substitutes trips by public transport. Car sharing has been preferred, because these trips are time-consuming and difficult to implement by public transport. However, the substitution effect is limited by the infrequent use of car sharing services. Members of car sharing organizations in the United States use car sharing services on average two or three times in a month (Transportation Research Board, 2005). On the other hand, Transportation Research Board (2005) also report that adoption of car sharing services generates many new trips by public transport, because public transport is used for a part of the entire trip, because of transportation demand management programs and because of a decrease in car-ownership. They argue that the complementary effect dominates the substitution effect. Also Meijkamp (2000) and KpVV (2009) report an increasing use of public transport in the Netherlands after the adoption car sharing services which indicates a dominating complementary effect.

The municipality of Amsterdam has also implemented a study to the substitution and complementary effects of car sharing services in Amsterdam. They conclude that the substitution effect dominates the complementary effect for trips by train. Approximately 25 percent of the car sharing population makes less use of the train after the adoption of car sharing and 13 percent travels more often by train. The use of metro, tram and bus is hardly changed. The decreasing use of the train as transportation mode is attributable to the change in mobility behavior of the group who had no private car available before adoption of car sharing (Gemeente Amsterdam, 2009). The Dutch government concludes that people who owned a private car before adoption use more often the train (+ 40 percent), bus, tram and metro (+ 20 percent) and the bike (+ 20 percent) and travel less by car (- 70 percent) after adoption of car sharing services. People who do not own a private car before do not show different mobility behavior after adoption. Because this group is the largest, there are in general no significant differences in mobility behavior before and after adoption of car sharing services (Ministerie van Verkeer en Waterstaat, 2003).

In general, it can be stated that it is difficult to determine which effect dominates. Most studies conclude the complementary effect is dominating, but the study of the municipality of Amsterdam reports a dominating substitution effect. It is possible that in smaller cities and rural areas the complementary effect will dominate. Car ownership is relatively low in Amsterdam and each shared car replaces 3,14 private cars. In smaller cities such as Wageningen and Houten car ownership is higher and each shared car replaces 5-6 private cars (KpVV, 2009).

2.4.3. Suitability of areas for car sharing

Providing accessibility from and to lower density areas and around big cities is important, because lower accessibility may result in a decreasing viability (SER, 2011). Accessibility from an individual perspective can be defined *as ''to which extent the spatial, infrastructural configuration allows people to reach different activities and at different times''* (Geurs *et al*., 2009, p.170). The spatial and infrastructural configuration of lower density areas is often not suitable for offering regular public transport connections in a cost-effective way, because of lower demand, a lower degree of concentration and different destinations of people which makes it difficult to bundle travelers. That's why in some rural areas demand-dependent public transportation systems replace regular public transport connections. On the one hand, substituting regular public transport connections for demand dependent public transport is often more cost-effective and offers more flexibility to people, but on the other hand introduction of these systems will lead to a reduction in the use of these lines, because advanced reservation is perceived as a barrier for use (MuConsult, 2006).

It is interesting to examine to what extent car sharing may provide an alternative in suburban and rural areas with lower densities. Car ownership rates and car use are significantly higher in rural and lower density areas, because the spatial and infrastructural configuration is oriented on car mobility (MuConsult, 2006). Car sharing services provide the same travel times and destination options and the same level of flexibility and accessibility to customers as private cars if they are parked close to customer’s home. In contrast to the operation of public transport, bundling of customers to the same destinations is not a necessary condition for offering car sharing services in a cost-effective way, unlike in the provision of public transport (Schoemaker, 2002). However, efficient exploitation of car sharing services also requires some degree of spatial concentration and demand from people. According KpvV (2009) the breakeven point of offering car sharing services is approximately equal to ten customers per shared car. That’s why offering these services in the smallest cores and most rural areas is often not feasible, but it gives perspective for other lower-density areas.

In higher density areas in bigger cities, car sharing is good alternative for some types of movement and enough support for offering car sharing services in a profitable way is usually available. A possible indication is given by relative high numbers of shared cars per inhabitant in Amsterdam and Utrecht (KpVV, 2013). However, the suitability of car sharing as transportation mode depends on the kind of trip. According Shaheen *et al.* (1998), car sharing is most attractive for movements with medium distances on tangential connections from suburbs to other lower density areas. For long distances, public transport is used and car sharing services have not been considered as an alternative, because of high variable costs. For short distances, walking and cycling are more attractive and cheaper modes of transportation. Moreover, in higher density areas, more kinds of destinations and facilities are within short distances and are therefore accessible by bike or walking and this may improve the position of cycling and walking in these areas (Wee, 2012). In this way, car sharing services fill the gap between cycling and public transport and could be positioned as alternative between the private car and public transport. Use of car sharing services is also an option for occasional vehicle needs, such as carrying heavy goods, to destinations which are not accessible by public transport or car sharing may be an alternative at times when public transport is not available (Shaheen *et al*., 1998). Car sharing services are in this way part of a complete sustainable mobility package. That’s why it can be stated that the attractiveness of car sharing is also dependent of the availability and quality of other transportation modes of the package, because these modes are an alternative to trips for which car sharing is not suitable. For example, if good public transport connections are lacking, it will be difficult to travel longer distances without a private car. Because the total mobility package is less attractive, car sharing is less attractive too. Conversely, if a location is highly accessible by public transport and a high number of activities are accessible within a certain time period, the total mobility package becomes more attractive.

The theory of car sharing as part of a total mobility package is supported by evidence that users of car sharing services make more use of public transport and cycling (KpVV, 2009;

Meijkamp, 2000; Nanninga & Eerdmans, 2006). As said before, good public transport connections are often lacking in rural and some suburban areas and because of lower densities, less destinations are accessible within short distances by bike or walking. That's why offering car sharing services in these areas and communities will probably not be profitable. However, offering car sharing services in lower density areas in cores on main public transport links may have potential. The public transportation network consists of connecting and enabling lines (Schoemaker, 2002). Connecting lines are the main connections in a network and are characterized by higher distances, fewer stops allowing for higher speeds and shorter travel times. Connecting lines are available at all geographical scales. Enabling lines can be characterized by many stops in order to provide access to mobility in many places as possible. This leads to lower speeds and longer travel times (Schoemaker, 2002). If more (connecting) public transport lines are available within a short distance, more activities may be accessible by public transport within a certain travel time.

A possible indication of the importance of connecting lines for offering car sharing services is given by the second highest ranking for the number of shared cars per capita in the Netherlands the non-urban municipality of Bunnik and also high number of shared cars per capita in the moderate urban municipalities Culemborg, Zutphen and Houten (KpVV, 2013). All of these smaller communities have good public transport connections with other cities. For short movements within these small cores, cycling may be an attractive alternative, because a certain supply of destinations and facilities is accessible within the cores. For example, the municipality of Houten has created a special cycling infrastructure which consists of bike lanes. Therefore, different destinations and facilities in the city are very good accessible by bike. The residential districts are only accessible by car through a peripheral road. The railway station is right in the heart of the town and every 15 minutes, a train to Utrecht, the central public transport hub in the Netherlands, is departing. Modal shares of cycling and walking for short distances (<7,5 km) are high with respectively 42% and 21% (Gemeente Houten, 2012). This structure make the total mobility package of cycling, car sharing services and public transport more attractive compared to the private car. The shared car will be positioned as an attractive mode for medium distance trips to other neighboring communities which are not good accessible by public transport or it offers an alternative for occasional trips.

2.5. Customer characteristics

For identifying suitable residential areas, it is important to know the customer characteristics of (potential) clients. Smart Agent (2011) has implemented a study to the potential of car sharing services in the province of Utrecht and has identified groups of customers based on their mobility behavior and socio-demographic characteristics. They conclude that customers of car sharing services have some common characteristics which will be discussed below.

Age

Most studies indicate that people in middle age categories are overrepresented in the population of car sharing customers. A study of Momo Car sharing (2010) under European car sharing customers indicates that the majority of customers is between 26 and 49 years old. KpVV (2009) indicates that car sharing customers in the Netherlands are on average approximately 40 years old. Smart Agent (2011) concludes that the majority of car sharing customers in the province of Utrecht is between the ages of 25 and 44. Finally, the Transportation Research Board (2005) indicates also that people between the ages of 25 and 34 and 35 and 44 years old are most represented in the category of car sharing customers in the USA and Canada.

The overrepresentation of this age group is probably due to the lifestyle of this group. Younger people travel often by public transport or did not have a driving license, while older people often have a family and they really need the flexibility private car for their family life (Kuhnimhof *et al.*, 2012).

Education
Most studies indicate that car sharing customers are more often higher educated than average. According Momo Carsharing (2010), car sharing customers in Europe have in general a better education than national averages. Also car sharing customers in the USA and Canada hold more often than average a bachelor degree or an advanced degree and people with low education are very underrepresented (Transportation Research Board, 2005). Also Smart Agent (2011) reports that car sharing customers in the province of Utrecht are on average higher educated. Only Meijkamp (2000) reports that the level of education has a negative impact on the adoption of car sharing services in the Netherlands. However, this study results from the year 2000 and the total number of car sharing customers has increased enormously since this year.

Household size
Car sharing customers live more often in smaller households. According KpVV (2009), Dutch car sharing customers have smaller households than the average household size of 2,2 persons in the Netherlands. Also Smart Agent (2011) and Momo Carsharing (2010) indicate that households of one and two persons are most represented among car sharing customers. The Transportation Research Board (2005) concluded that only 25 percent of car sharing customers lives in households with children and that average household size of car sharing customers is two persons.

Car ownership
Most car sharing customers have no private car available in their households. According Momo Carsharing (2010), Smart Agent (2011) and Transportation Research Board (2005), car sharing customers own less often a private car compared to the population average. Also Meijkamp (2000) indicates a negative relationship between the adoption of car sharing services and car ownership before adoption. Moreover, car sharing customers in the Netherlands make less often use of private cars for commuting to work than average (KpVV, 2009; Meijkamp, 2000).

Income
Some studies indicate that car sharing customers has also higher incomes on average. According KpVV (2009), car sharing customers in the Netherlands have on average higher incomes compared to total population. Also the Transportation Research Board (2005) concludes that car sharing customers are more often at the higher end of the income scale. Momo Carsharing (2010) indicates that European car sharing customers are more often

employed or self-employed and unemployed people are largely absent as car sharing customers.

2.6. Hypotheses

This chapter has given insight in the relevance of car sharing with respect to sustainable mobility and into relations between the use of car sharing services and other important factors. It may be concluded that offering car sharing in residential areas is part of a total sustainable mobility package which may be offered to customers. In this package, car sharing is most suitable for tangential movements with medium distances and it may be an alternative for occasional vehicle needs, such as the transportation of heavy goods, to destinations which are not accessible by public transport and bike and at times that public transport is not available. For short trips, the bike can be used and for longer trips public transport may act as the dominant mode of transportation at these distances, because these modes offer usually a better price/quality ratio. The use of cycling as mode of transport and the accessibility by public transport are therefore probably important conditions for the attractiveness of car sharing. Also density is an important condition, because more kinds of destinations and facilities are accessible by bike and walking.

Also characteristics of car sharing customers are probably important for determining the use of car sharing services. Car sharing customers are on average more often between 25 and 44 years old, have smaller households, have higher incomes, are higher educated and the degree of car ownership is lower. The theoretical findings lead to the following hypotheses:

Hypothesis 1: There exists a positive relationship between the accessibility provided by public transport and the use of car sharing services

Hypothesis 2: There exists a positive relationship between the share of cycling in the modal split and the use of car sharing services

Hypothesis 3: There exists a positive relationship between density and the use of car sharing services

Hypothesis 4: There exists a positive relationship between the presence of people between the ages of 25 and 44 years old and the use of car sharing services

Hypothesis 5: There exists a positive relationship between the level of education and the use of car sharing services

Hypothesis 6: There exists a negative relationship between household size and the use of car sharing services

Hypothesis 7: There exists a negative relationship between car ownership and the use of car sharing services

Hypothesis 8: There exists a positive relationship between the level of income and the use of car sharing services

3. Data and methodology

In this chapter, the data and methodology will be discussed. Section 3.1 explains the methodology which will be used. In section 3.2, the data selection will be discussed. Section 3.3 is about the model composition. Finally, in section 3.4 the selected data will be tested on general statistical assumptions.

3.1. Methodology

For implementing this research, mainly quantitative methods have been used. Quantitative research strategies test scientific theories are tested based on numbers and values (Bryman, 2008). The nature of quantitative research is in general deductive, which means that hypotheses are derived from scientific theories (Bryman, 2008). However, this research has also important qualitative characteristics. Often, quantitative research methods do not control for the local context, but by including various relevant indicators of municipalities the local context has also been taken into account.

The research questions will be answered and the hypotheses will be tested by performing stepwise multiple regression analyzes. In this way, it is possible to create models which includes only a combination of relevant explanatory variables with a significant impact[1] on the dependent variable and to prevent influence of insignificant factors on the coefficients of other variables. The multiple regression analyzes corrects also for interdependent effects between explanatory variables (Bavel, 2006). Because of the large sample size, a significance level of 0.10 is reasonable[2].

For estimating the coefficients of the model the ordinary least squares method has been used. This method predicts a model based on the minimized sum of squared vertical distances between the actual data and the optimal predicted linear relationship (Stock & Watson, 2007). However, in order to guarantee unbiasedness of this method, some assumptions have to be met. The first assumption is linearity of the estimated parameters. In the case that the variables incorporate non-linearities, the variables will be transformed into logarithms. A second assumption is the random composition of the sample which has been fulfilled. Another assumption is that perfect linear relationships between explanatory variables may not exist. However, high correlation between exogenous variables which is called imperfect multicollinearity can also be considered as a problem and may lead to wrong estimations (Stock & Watson, 2007). That's why also some explanatory variables which have a correlation of 0.70 or higher have not been included in the models.

A fourth restriction is that explanatory variables should be exogenous. For testing the exogeneity and the specification of the functional form, the Ramsey RESET test has been implemented for all models. In order to test hypotheses about parameters it is also needed to make the assumption of homoskedasticity which means that the variances of the error

[1] A relationship is significant if it is very likely that the assumed relation is not based on coincidence. In the case of significance, the null-hypothesis that the coefficient of an variable is zero and has no impact will be rejected in favor of an alternative hypothesis that the coefficient is not equal to zero and the variable has impact (Stock & Watson, 2007).

[2] The level of significance is a pre-specified level at which the null-hypothesis will be rejected. If the probability that the null-hypothesis is correct (p-value) is lower than the significance level, the null-hypothesis will be rejected.

terms are the same. The Breusch-Pagan test has been implemented for all models in order to test for homoskedasticity. If there is evidence of heteroskedasticity (variances of error terms are not the same), standard errors which are robust for heteroskedasticity have been used. A last assumption is that error terms are independent of the explanatory variables and have to be normally distributed. Because the sample is large, estimators are already approximately normally distributed and this assumption has been fulfilled (Stock & Watson, 2007). If all assumptions hold, ordinary least squares can be considered as the best linear unbiased estimator (Stock & Watson, 2007).

3.2. Data selection

For this research, a sample of 100 municipalities has been selected. The selected municipalities represent the highest-ranked communities with respect to the number of shared cars in relation to the total population in 2011. These data are provided by KpVV (2013) and give an indication about the number of car sharing customers in a municipality, because offering traditional car sharing services is highly demand driven in the Netherlands. Moreover, data for 2011 hardly include new concepts of car sharing services which are less demand driven, such as peer to peer car sharing (KpVV, 2013).

Data about public transport accessibility are provided by the ''Nationale Bereikbaarheidskaart (2013)''. Data about both inward and outward accessibility are available. Inward accessibility has been measured as the number of people who can reach a specific postcode area by public transport within time intervals of respectively 15, 30, 60, 90 and 120 minutes. Outward accessibility has been measured as the number of people that can be reached within time periods of respectively 15, 30, 60 and 120 minutes from a specific postcode area by public transport. The ''Nationale Bereikbaarheidskaart (2013)'' does not include the accessibility to German and Belgian areas which means that the accessibility of cities close to the borders of the country and with good public transport connections to Germany and Belgium is less reliable. However, cities close to the borders are still included in the sample, because the assumption has been made that cross-border mobility is relatively limited compared to domestic mobility, because people are mostly oriented on their home country due to a limited number of cross-border public transport connections, administrative and language differences (DHV, 2007; SER, 2001; TC Tubantia, 2012).

Other available indicators for measuring public transport are the average proximity of train stations and the average proximity of large transfer stations. These data are accessible on municipality level and are provided by CBS StatLine (2013). Data about the share of cycling in modal split and about the modal share of cycling on short distances are also available for the 100 selected municipalities and are provided by KpVV (2013) and give an indication of the use of cycling as mode of transport. For measuring density, two indicators are available at municipal level. KpVV (2013) has categorical ordered data available about the degree of urbanity, varying from extremely urban (>2.500 addresses per km²) to non-urban (<500 addresses per km²). KNIG (2013) provides also data about population density measured by the number of inhabitants per km². Data about average household size and the share of total population in a municipality between 25 and 45 years old are also provided by KNIG (2013). Also data with respect to the share of total population between 20 and 25 years old are included, because Smart Agent (2011) argues that younger people are more often potential car sharing customers.

Data with respect to the number of private cars, average disposable incomes and the number of higher-educated people are provided by CBS StatLine (2013). The number of higher-educated people in a municipality is only available for municipalities with more than 30.000 inhabitants. Furthermore, an indication of a group of municipalities belonging to the Randstad has been made and will act as control variable. This has been done because of many differences which exist between the Randstad and other parts of the Netherlands with respect to for example the use of public transport and congestion problems, the behavior of people and spatial conditions (Ministeries VWS & VROM, 2004). Municipalities have been considered as Randstad municipalities if they are located in the Randstad area according TNO (2012). TNO (2012) defines the Randstad as the four Randstad provinces Utrecht, Zuid-Holland, Noord-Holland and Flevoland minus the Randstad outlying areas. This means that the Randstad consists of the urban areas and the 'Groene Hart'. The list whether a municipality is located in the Randstad has been included in appendix I.

All data are from the year 2011, except for the data about public transport accessibility (2008), the average disposable income (2010) and the share of cycling in modal split (average about period 2004-2008), because these data are not available for the year 2011. However, it is plausible to make the assumption that public transport accessibility, the share of cycling in the modal split and average disposable incomes have not been changed significantly. Moreover, only a few municipalities have had to deal with a small-scale municipal reclassification (CBS StatLine, 2013). In this case, the largest former municipality has been taken in order to approximate the data for the current municipality. Because of the assumptions made and the absence of large-scale reclassifications it is expected that the use of these data has no major impact on the validity and reliability of this research.

3.3. Model composition

Variable description

The number of shared cars per 100.000 inhabitants will act as dependent variable in this case. All other variables are explanatory in nature. Public transport accessibility has been calculated as the average of the inward and outward accessibility. For bigger municipalities (>100.000 inhabitants), the average accessibility levels of five postcodes in respectively the center, the north, south, east and west have been calculated in order to correct for differences in accessibility between different parts of the municipality. For small municipalities (<100.000 inhabitants), the postcode of the center area of the largest town in the municipality has been taken as starting point. Because of the limited size, it is not necessary to correct for differences in accessibility, because these differences are small and the number of postcode areas is often limited.

The data about the number of private cars and the number of higher-educated people are divided by total population in order to correct for the size of a municipality. All other data are taken directly from the different sources. Table 3 contains a list of all variables which will be used for the composition of the model. Because data with respect to education level are only available for municipalities with more than 30.000 inhabitants, the variable '*higheduc*' has some missing values.

Table 3: List of variables

Variables	Description
shcarspop	number of shared cars per 100.000 inhabitants
avdistransf	average road distance of all inhabitants to an important transfer station in km
avdistrain	average road distance of all inhabitants to the nearest train station in km
avaccpt15	average of the number of people which have access or can be accessed within 15 minutes by public transport
avaccpt30	average of the number of people which have access or can be accessed within 30 minutes by public transport
avaccpt90	average of the number of people which have access or can be accessed within 90 minutes by public transport
cyclshortdis	share of cycling in total number of trips shorter than 7,5 km
popdens	number of people per km^2
durban1	dummy whether takes value 'one' if a municipality is highly urbanized (more than 2500 addresses per km^2) and 'zero' otherwise
durban2	dummy whether takes value 'one' if a municipality is strong urban (1500-2500 addresses per km^2) and 'zero' otherwise
durban3	dummy whether takes value 'one' if a municipality is moderate urban (1000-1500 addresses per km^2) and 'zero' otherwise
durban4	dummy whether takes value 'one' if a municipality is little urban (500-1000 addresses per km^2) and 'zero' otherwise
durban5	dummy whether takes value 'one' if a municipality is non-urban (less than 500 addresses per km^2) and 'zero' otherwise
caturban	categorical variable whether a municipality falls in urbanity category 1, 2, 3, 4 or 5
age2544	percentage of inhabitants between 25 and 44 years old
age2025	percentage of inhabitants between 20 and 25 years old
higheduc	percentage of inhabitants with a college or university degree
avhousehold	number of persons per household
carownership	number of inhabitants per private car
avincome	average disposable income per inhabitant in euro's (x1000)
drandstad	dummy whether takes value 'one' if a municipality is located in the Randstad and 'zero' otherwise

Source: Own interpretation based on CBS StatLine (2013), KNIG (2013), KpVV (2013) and Nationale Bereikbaarheidskaart (2013)

Multicollinearity

As said in section 3.1, multicollinearity between exogenous variables may lead to wrong estimations and that's why some variables have not been included in the models at the same time. The correlation table in appendix I shows that the variables '*avaccpt60*', '*avaccpt90*' and '*avaccpt120*' are highly correlated with each other. The variable '*avaccpt60*' is also highly correlated with '*avaccpt30*'. That's why we only include the variables '*avaccpt15*', '*avaccpt30*' and '*avaccpt90*' in the models. In this way, the impact of local accessibility can be measured by public transport by including the average accessibility by public transport within 15 minutes and the impact of regional and supra-regional/national accessibility has been measured by including respectively the variables for accessibility by public transport within 30 and 90 minutes.

Not surprisingly, also the modal share of cycling and the modal share of cycling on short distances are highly correlated with each other. Because '*cyclshortdis*' is stronger correlated with the dependent variable, this variable will be included in the model. Furthermore, '*popdens*' and '*caturban*' are highly correlated.

Data transformations
In order to incorporate non-linear relationships and get better predictions some of the variables are transformed into logarithms which leads to a normal distribution of the data. The dependent variable was somewhat positively skewed and that's why a logarithmic transformation has been performed. Also for population density, average income, average distance to train stations, average distance to transfer stations, regional accessibility by public transport and the modal split of cycling on short distances, a logarithmic transformation will lead to a more normal distribution of the data. All other variables are approximately normally distributed. The distributions of the transformed data are displayed in appendix I.

It could be that the impact of the indicators on the availability differs per region or type of municipality. In order to correct for this difference, interaction terms will be created for each continuous variable with the dummies for urbanity and the dummy for Randstad municipalities. The lowest category of urbanity which is represented by variable '*durban5*' serves as the base category. Interactions only have been included if they are statistically significant at a 10 percent level and the outcomes of an F-test indicate that the model with interaction terms predicts better than the model without these terms.

Furthermore, it is possible to control for non-linear relationships by creating quadratic terms in the independent variables (Stock & Watson, 2007). Often, the slope of a regression function is not constant, but rather declining or increasing marginal relationships exist. The decision to include only quadratic variables and not polynomials of a higher degree is based on the fact that increasing the degree means the inclusion of more variables (of lower order) which leads to imprecise estimations (Stock & Watson, 2007). Only quadratic variables which are statistically significant have been included in the models.

Interpretation
Because the dependent variable is a log transformation and the independent variables are either logarithms or level variables, two types of interpretations have been used in order to explain the magnitude of the coefficients. If both the dependent and independent variables are logarithms, the magnitude of the coefficient can be interpreted in terms of percentage change of both variables, keeping all other factors fixed (Stock & Watson, 2007). If the dependent variable is a logarithm and the explanatory is in level terms, the coefficient must be multiplied by hundred, in order to interpret the magnitude in terms of a percentage

change in the dependent variable for a unit change in the independent variable (Stock & Watson, 2007).

Model setup

For testing the effect of the different variables, four different types of models have been estimated and they are shown below. The single impact of each indicator will be estimated by a restrictive model. In the second type of models, the effect of the common spatial characteristics on the dependent variable will be estimated. The third type of models estimates the relation between the customer characteristics and the dependent variable. Finally, a full model which includes all explanatory variables has been composed. Because data about education are only available for 69 municipalities, also a customer characteristics and a full model will be estimated without the inclusion of education. Furthermore, for each type of model, also a model which includes non-linear terms has been estimated. In all the models, signs of the estimated coefficients and significance of the variables have been analyzed. In the restricted models, also the magnitudes of the coefficients have been precisely interpreted in the restricted models. Moreover, the R-squared of the estimated models will be interpreted, because this term indicates how much of the variance in the dependent variable can be explained by the explanatory variables. In the models with more variables, the adjusted R-squared has been analyzed, because this one corrects for the number of variables which have been included (Stock & Watson, 2007).

Restrictive model

$$\ln shcarspop = f(independentvariable) + \varepsilon$$

Spatial characteristics model

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, drandstad) + \varepsilon$$

Customer characteristics model

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, \ln avincome, carownership) + \varepsilon$$

$$\ln shcarspop = f(age2025, age2545, avhousehold, \ln avincome, carownership) + \varepsilon$$

Full model

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, age2025, age2545, higheduc, avhousehold, \ln avincome, carownership, drandstad) + \varepsilon$$

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, age2025, age2545, avhousehold, \ln avincome, carownership, drandstad) + \varepsilon$$

4. Data analysis and interpretation

In this chapter, the actual analysis of the data will take place and the different relationships will be examined. In section 4.1, the estimations and analyses of the restricted models are implemented. Section 4.2 analyses the model which represents the impact of customer characteristics. In section 4.3, the impact of spatial characteristics on the use of car sharing services has been analyzed. Finally, section 4.4 presents the analyses of the full model.

4.1. Restricted models

By performing regression analyses of restricted models, the individual effect of each explanatory variable on the use of car sharing services can be estimated. Interaction terms and polynomials will only be added to the restricted models if they are significant and well-specified. This section is divided in subsections which represents the assumed relationships in the hypotheses. In the last subsection, a consideration about the results has been presented.

4.1.1. Public transport

This subsection is about the impact of the use of public transport on the use of car sharing services. The impact of the variables with respect to the public transport accessibility per 15, 30 and 90 minutes and the average distances to train stations and transfer stations is estimated both individually and collectively..

Average distance train stations

The relation between average distance to train stations and the number of shared cars per 100.000 inhabitants is examined by using the following equation:

$$\ln shcarspop = f(\ln avdistrain) + \varepsilon$$

In order to produce unbiased and consistent results, both the Ramsey Reset test for functional form misspecification and the Breusch-Pagan test for heteroskedasticity have been implemented. There is no evidence of misspecification according the Ramsey Reset test given a significance level of 0.10 (see appendix II). Moreover, the Breusch-Pagan test for heteroskedasticity indicates that there is no evidence of heteroskedasticity given a significance level of 0.10 (see appendix II), so the results of this regression are unbiased and consistent.

Source	SS	df	MS
Model	1.14335748	1	1.14335748
Residual	56.5010067	98	.576540885
Total	57.6443642	99	.582266305

Number of obs	= 100
F(1, 98)	= 1.98
Prob > F	= 0.1622
R-squared	= 0.0198
Adj R-squared	= 0.0098
Root MSE	= .7593

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_avdistr~n	-.2549381	.1810334	-1.41	0.162	-.6141931	.1043169
_cons	2.7674	.2619914	10.56	0.000	2.247487	3.287313

The negative sign of the coefficient of '*ln_avdistrain*' indicates that a negative relationship exists between the average distance to train stations and the number of shared cars per 100.000 inhabitants, which means the greater the average distance to a train station, the smaller the use of car sharing services in a municipality. However, because the p-value of

0.162 exceeds the significance level of 0.10, there is no evidence of a significant relationship between the variables.

Average distance transfer stations
The relationship between average distance to important transfer stations and the number of shared cars per 100.000 inhabitants have been examined by using the following equation:

$$\ln shcarspop = f(\ln avdistransf) + \varepsilon$$

However, the results show that the interaction term between the dummy for Randstad municipalities and the continuous variable are statistically significant at a 10 percent level and the outcomes of an F-test show that the model with interactions predicts better compared to the model without these terms, so the simple model has been extended with interaction terms. Moreover, the Ramsey Reset test and Breusch-Pagan test indicate that there is no evidence of respectively misspecification of the functional form or heteroskedasticity according (see appendix II), which means that the results are consistent and unbiased.

Source	SS	df	MS		
				Number of obs	= 100
				F(3, 96)	= 4.53
Model	7.14834687	3	2.38278229	Prob > F	= 0.0051
Residual	50.4960173	96	.526000181	R-squared	= 0.1240
				Adj R-squared	= 0.0966
Total	57.6443642	99	.582266305	Root MSE	= .72526

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_avdistr~f	-.0206544	.1510172	-0.14	0.892	-.3204211	.2791124
drandstad	1.430321	.5075956	2.82	0.006	.4227518	2.43789
rstd_transf	-.6009519	.2356713	-2.55	0.012	-1.068756	-.1331481
_cons	2.348272	.3312249	7.09	0.000	1.690796	3.005748

There exists a negative relationship between the average distance to important transfer stations and the number of shared cars, which means the greater the average distance to transfer stations, the smaller the use of car sharing services in a municipality. However, the magnitude of this effect differs for Randstad and non-Randstad municipalities. A one percent increase in the average distance to transfer stations in non-Randstad municipalities causes a very small decrease in the number of shared cars per 100.000 inhabitants of 0.02 percent, while for Randstad municipalities this decrease is equal to 0.62, holding all other factors which are included in the error term (ε) constant. Because the dummy for Randstad cities is positively significant at the 10 percent level, there Randstad municipalities have also a higher intercept with the y-axis in the case that distance is equal to zero, which means that Randstad municipalities have a higher expected level of car sharing services. It can be concluded that proximity to important transfer stations is a more important condition for the availability of car sharing services in Randstad cities than in non-Randstad cities.

The average distance to transfer stations differs also between moderate urban municipalities and other municipalities, because this interaction is strongly statistically significant at a 10 percent level with a p-value of 0.011. Moreover the model with interactions estimates better than the model without interactions and there is no evidence of functional form misspecification or heteroskedasticity (see appendix II).

Source	SS	df	MS		
Model	6.77729672	3	2.25909891	Number of obs =	100
Residual	50.8670675	96	.529865286	F(3, 96) =	4.26
				Prob > F =	0.0072
Total	57.6443642	99	.582266305	R-squared =	0.1176
				Adj R-squared =	0.0900
				Root MSE =	.72792

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_avdistr~f	-.490515	.1507118	-3.25	0.002	-.7896755	-.1913546
durban3	-1.476076	.5413407	-2.73	0.008	-2.550629	-.401523
urban3_tra~f	.6277722	.2433766	2.58	0.011	.1446736	1.110871
_cons	3.45387	.3117488	11.08	0.000	2.835054	4.072686

The results show that a one percent increase in the average distance to transfer stations in municipalities which are not moderate urban leads to a decrease in the number of shared cars per 100.000 inhabitants of 0.49 percent, while a one percent increase in moderate urban municipalities leads to an increase in the availability of car sharing services by 0.14 percent, keeping other factors fixed. Car sharing services are probably more available in moderate urban with a larger average distance to transfer stations. Furthermore, also the expected value of car sharing services when average distance is equal to zero is lower in moderate urban municipalities, because the dummy for moderate urban cities is negatively significant at the 10 percent level.

Local accessibility public transport

The relationship between the average accessibility within 15 minutes by public transport as indicator for local accessibility by public transport and the number of shared cars per 100.000 inhabitants is non-linear and can be represented by the next equation:

$$\ln shcarspop = f(avaccpt15, avaccpt15^2) + \varepsilon$$

There is no evidence of misspecification of the functional form or heteroskedasticity according the Ramsey Reset test and Breusch-Pagan test (see appendix II), so the results can be interpreted.

Source	SS	df	MS		
Model	7.15366156	2	3.57683078	Number of obs =	100
Residual	50.4907027	97	.520522708	F(2, 97) =	6.87
				Prob > F =	0.0016
Total	57.6443642	99	.582266305	R-squared =	0.1241
				Adj R-squared =	0.1060
				Root MSE =	.72147

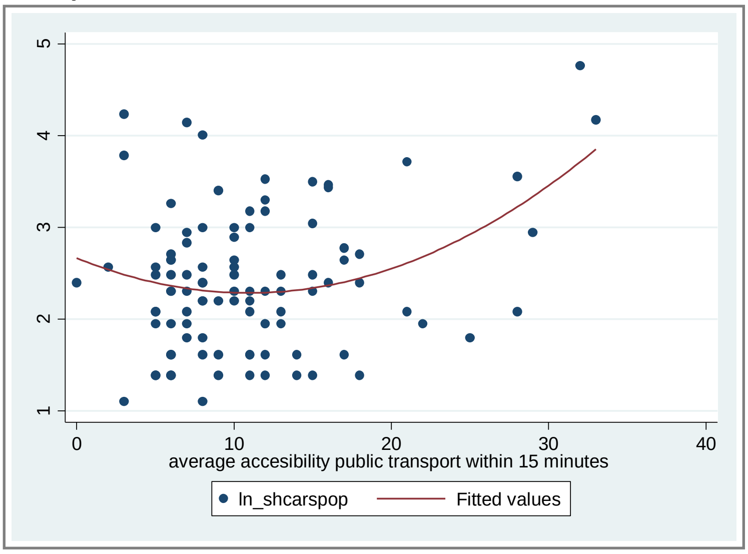
ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
avaccpt15	-.0700616	.0390165	-1.80	0.076	-.1474985	.0073753
avaccpt152	.0032123	.0012075	2.66	0.009	.0008157	.0056088
_cons	2.665947	.2611639	10.21	0.000	2.147609	3.184285

According the regression results, local accessibility is statistically significant at a 10 percent level and the coefficient for the squared average accessibility by public transport within 15 minutes is positive, which means that the pattern of the regression is convex. However, coefficients in polynomial regressions do not have a simple interpretation, because the change in the dependent variable is not the same for each value of average accessibility. That's why the regression function has been plotted in figure 3 to illustrate the change. By taking the derivative, it is possible to calculate the value of local accessibility at the minimum level of shared cars, which is approximately equal to 11.7[3]. This means that the assumed

[3] By taking the derivative of the function for the logarithm of car sharing services with respect to the variable '*avaccpt15*' and equating the derivative to zero, the value for local accessibility by public transport at the minimum has been calculated. $\frac{d \ln shcarspop}{davaccpt15} = -0.07 + 0.006avaccpt15$, $avaccpt15 = 11{,}67$

positive relationship between local accessibility by public transport and presence of car sharing services is only valid from a minimum access of 11.700 people within 15 minutes. Furthermore, the explanatory power is relatively high for one model with an adjusted R-squared of almost 11 percent.

Figure 3: Plot of presence of car sharing services versus local accessibility by public transport



Source: Own processing

Also the interaction for strong urban municipalities with the indicator for local accessibility is statistically significant at a 10 percent level and the outcomes of an F-test (see appendix II) indicate that this model predicts better compared to a model without interaction. Moreover, there is no evidence of misspecification or heteroskedasticity (see appendix II), so the results can be interpreted.

Source	SS	df	MS
Model	8.86061985	3	2.95353995
Residual	48.7837444	96	.508164004
Total	57.6443642	99	.582266305

Number of obs =	100
F(3, 96) =	5.81
Prob > F =	0.0011
R-squared =	0.1537
Adj R-squared =	0.1273
Root MSE =	.71286

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
avaccpt15	.0498473	.0130609	3.82	0.000	.0239216	.075773
durban2	.7555536	.3132775	2.41	0.018	.1337027	1.377404
urban2_pt15	-.0804219	.0254889	-3.16	0.002	-.131017	-.0298267
_cons	1.899377	.1749347	10.86	0.000	1.552135	2.24662

In this model, the positive relationship between local accessibility by public transport and the presence of car sharing services still holds for municipalities which are not strong urban. An increase in the average accessibility within 15 minutes by one unit in these types of municipalities causes an increase in the number of shared cars per 100.000 inhabitants of 5 percent, keeping other factors fixed. However, for strong urban municipalities a negative and strongly significant relationship exists. An additional unit increase in the local accessibility by public transport means a decrease in the presence of car sharing services per 100.000 inhabitants by 3 percent. However, because the dummy for strong urban municipalities is positively significant, the expected level of car sharing services when average accessibility is equal to zero is higher in strong urban municipalities. The independent variables explain together almost 13 percent of the variance in the dependent variable.

Regional accessibility by public transport

The relationship between the average accessibility within 30 minutes by public transport and the number of shared cars per 100.000 inhabitants is non-linear can be represented by the next equation:

$$\ln shcarspop = f(\ln avaccpt30\,, \ln avaccpt30^2) + \varepsilon$$

According the Ramsey Reset test and Breusch-Pagan test, there is no evidence of functional form misspecification or heteroskedasticity (see appendix II), so we can interpret the regression results.

Source	SS	df	MS
Model	5.25171176	2	2.62585588
Residual	52.3926525	97	.540130438
Total	57.6443642	99	.582266305

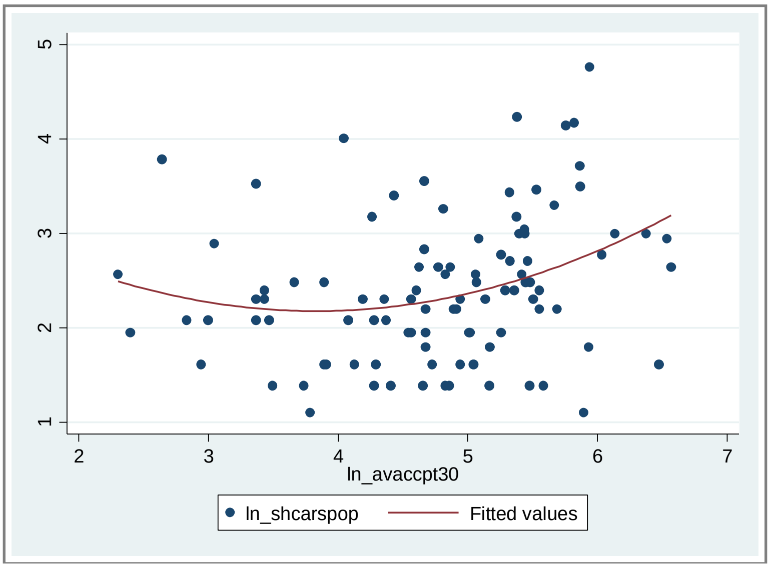
Number of obs =	100
F(2, 97) =	4.86
Prob > F =	0.0097
R-squared =	0.0911
Adj R-squared =	0.0724
Root MSE =	.73494

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_avaccpt30	-1.036119	.6055691	-1.71	0.090	-2.238006	.1657675
ln_avacc~302	.1352224	.0664517	2.03	0.045	.0033342	.2671105
_cons	4.161693	1.349302	3.08	0.003	1.483702	6.839684

According the model, regional accessibility is significant at a 10 percent level and the coefficient of the quadratic accessibility by public transport within 30 minutes is positive, which means the curve as convex shape. This has been illustrated in the figure below. There exists only a small positive relationship between regional accessibility by public transport and car sharing services for access by public transport to more than 41.000 people within 30 minutes[4]. The explanatory power is also not very high with an adjusted R-squared of 7 percent.

[4] $\frac{d\ln shcarspop}{d\ln avaccpt30} = -1.04 + 0.28\ln avaccpt30$, $\ln avaccpt30 = 3{,}71, avaccpt30 = e^{3.71} = 40.85$

Figure 4: Plot of presence of car sharing services versus regional accessibility by public transport



Source: Own processing

National/supra-regional accessibility by public transport

For estimating the linear relationship between the dependent variable and the average accessibility within 90 minutes by public transport, the next equation can be used:

$$\ln shcarspop = f(avaccpt90) + \varepsilon$$

Because the interaction between the dummy for Randstad municipalities and national accessibility by public transport is statistically significant and an F-test indicates that this model predicts better compared to a model without interactions (see appendix II), the interaction has been included in the model. Moreover, there is no evidence of misspecification of the functional form or heteroskedasticity (see appendix II), so the results can be considered as unbiased and consistent.

Source	SS	df	MS
Model	14.7872334	3	4.92907778
Residual	42.8571309	96	.446428446
Total	57.6443642	99	.582266305

Number of obs = 100
F(3, 96) = 11.04
Prob > F = 0.0000
R-squared = 0.2565
Adj R-squared = 0.2333
Root MSE = .66815

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
avaccpt90	.0001585	.0000676	2.34	0.021	.0000243	.0002927
drandstad	-1.038093	.4034313	-2.57	0.012	-1.838898	-.2372879
rstd_pt90	.0001598	.0000924	1.73	0.087	-.0000236	.0003432
_cons	1.865743	.2129055	8.76	0.000	1.443129	2.288357

The results indicate a small positive and significant relationship between the average accessibility within 90 minutes by public transport and the number of shared cars per 100.000 inhabitants for non-Randstad municipalities. If the average accessibility within 90 minutes by public transport increases by one additional unit, the average number of shared cars per 100.000 inhabitants increases by only 0.02 percent, keeping all other factors included in the error term fixed. For Randstad cities, a one unit increase in national accessibility means an increase in the number of shared cars per 100.000 inhabitants by 0.04 percent, keeping other factors fixed. The expected level of car sharing services when national accessibility is equal to zero is lower in Randstad-municipalities, because the dummy for Randstad municipalities is significant at a 10 percent level. The explanatory power of the model is relatively high for one variable with an adjusted R-squared of 0.23.

Public transport variables
The common effect of the best fitting public transport variables can be estimated by using the next equation:

$$\ln shcarspop = f(avaccpt15, avaccpt15,^2 avaccpt90, \ln avdistransf, rstd\_transf) + \varepsilon$$

The interactions between Randstad municipalities and the distance to important transfer stations and the square for local accessibility by public transport are still significant in the new model. Moreover, an F-test indicates that the inclusion of these terms leads to a better model (see appendix II), so these terms have also been included. There is no evidence of heteroskedasticity or misspecification according respectively the Breusch-Pagan test and the Ramsey Reset test (see appendix II), so the results below can be considered as consistent and unbiased.

Source	SS	df	MS		
Model	20.0266607	5	4.00533213	Number of obs =	100
Residual	37.6177035	94	.400188336	F(5, 94) =	10.01
				Prob > F =	0.0000
Total	57.6443642	99	.582266305	R-squared =	0.3474
				Adj R-squared =	0.3127
				Root MSE =	.6326

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
avaccpt15	-.0784676	.0343189	-2.29	0.024	-.1466085	-.0103267
avaccpt90	.0002128	.0000422	5.05	0.000	.0001291	.0002965
ln_avdistr~f	-.1325403	.1078458	-1.23	0.222	-.3466707	.08159
rstd_transf	-.1792867	.0729091	-2.46	0.016	-.3240494	-.0345239
avaccpt152	.0030061	.0010622	2.83	0.006	.0008971	.0051151
_cons	2.387648	.3627086	6.58	0.000	1.667482	3.107815

In this model, the positive and statistically significant relationships between local and national accessibility by public transport and the presence of car sharing services still hold, although the impact of national accessibility is very small. However, the positive relationship between local accessibility by public transport and presence of shared cars is only valid for an access by public transport within 15 minutes which is higher than 13.300 people[5]. Also the negative and significant relationship between the average distance to transfer stations and car sharing services still holds. For Randstad municipalities, this relationship is even more negative. Because the dummies for Randstad-municipalities and strong urban municipalities are not significant, the expected level of car sharing services is the same for all municipalities if all regressors are equal to zero.

Also other indicators for public transport have no significant impact on the dependent variable if their common impact has been tested. The adjusted R-squared indicates that 31 percent of the variance in the dependent variable can be explained by the significant public transport variables.

5 $\frac{d \ln shcarspop}{davaccpt15} = -0.08 + 0.006avaccpt15 \text{ , } avaccpt15 = 13.33$

4.1.2. Cycling

The linear relationship between the share of cycling in the modal split on distances shorter than 7,5 kilometer and the number of shared cars per 100.000 inhabitants can be represented by the next equation:

$$\ln shcarspop = f(\ln cyclshortdis) + \varepsilon$$

According the Ramsey Reset test and the Breusch-Pagan test there is no evidence of respectively functional form misspecification and heteroskedasticity (see appendix II), so the results below are consistent and unbiased.

Source	SS	df	MS		
				Number of obs =	100
				F(1, 98) =	1.63
Model	.941076493	1	.941076493	Prob > F =	0.2052
Residual	56.7032877	98	.578604977	R-squared =	0.0163
				Adj R-squared =	0.0063
Total	57.6443642	99	.582266305	Root MSE =	.76066

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ln_cyclsho~s	.5767399	.4522292	1.28	0.205	-.3206943	1.474174
_cons	.3528892	1.618159	0.22	0.828	-2.858294	3.564073

According the results, there exists a positive relationship between the share of cycling in modal split on short distances and the number of shared cars per 100.000 inhabitants. However, this relationship is not statistically significant, because the p-value of 0.21 exceeds the significance level of 0.10.

4.1.3. Density

The linear relationship between the number of people per square kilometer and the number of shared cars per 100.000 inhabitants can be represented by the next equation:

$$\ln shcarspop = f(\ln popdens) + \varepsilon$$

There is no evidence of heteroskedasticity and functional form misspecification (see appendix II), so the results below can be interpreted.

Source	SS	df	MS		
				Number of obs =	100
				F(1, 98) =	11.43
Model	6.0227161	1	6.0227161	Prob > F =	0.0010
Residual	51.6216481	98	.526751511	R-squared =	0.1045
				Adj R-squared =	0.0953
Total	57.6443642	99	.582266305	Root MSE =	.72578

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ln_popdens	.2691181	.0795884	3.38	0.001	.1111776	.4270587
_cons	.5583549	.5536473	1.01	0.316	-.5403402	1.65705

According the model, a strong significant and positive relationship exists between the two variables. A one percent increase in the number of people per square kilometer will lead to an increase in the number of shared cars per 100.000 inhabitants by 0.27 percent, holding all other factors included in the error term fixed. The explanatory variable accounts for almost 10 percent of the variance in the dependent variable, according the adjusted R-squared.

4.1.4. Age

Age category 20-25

The linear relationship between the share of younger people between 20 and 25 years old in total population on the one hand and the number of shared cars per 100.000 inhabitants can be expressed by the next equation:

$$\ln shcarspop = f(age2025) + \varepsilon$$

According the outcomes of the Breusch-Pagan test and the Ramsey Reset test, there is no evidence of respectively heteroskedasticity and misspecification of the functional form (see appendix II) and therefore we can interpret the results from the regression.

Source	SS	df	MS
Model	3.92007363	1	3.92007363
Residual	53.7242906	98	.548207047
Total	57.6443642	99	.582266305

Number of obs	= 100
F(1, 98)	= 7.15
Prob > F	= 0.0088
R-squared	= 0.0680
Adj R-squared	= 0.0585
Root MSE	= .74041

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age2025	.0977859	.036568	2.67	0.009	.0252179	.170354
_cons	1.829529	.2308714	7.92	0.000	1.371372	2.287686

According the model, a positive and significant relationship exists between the dependent variable and the share in total population of people between the ages of 20 and 25. An increase in the share of younger people between 20 and 25 years with an additional unit will lead to an increase in the number of shared cars per 100.000 inhabitants with 9.78 percent, holding all other factors fixed.

Age category 25-45

The non-linear relationship between the share in total population of people between the ages 25 and 45 years and the number of shared cars per 100.000 inhabitants can be represented by the next formula:

$$\ln shcarspop = f(age2545, age2545^2) + \varepsilon$$

There is no evidence of functional form misspecification or heteroskedasticity according the Ramsey Reset test and the Breusch-Pagan test (see appendix II), so the regression results can be interpreted.

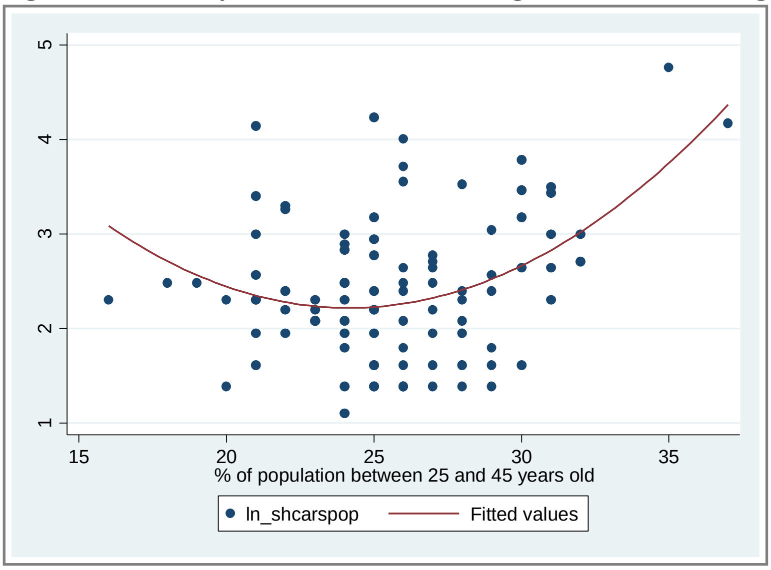
Source	SS	df	MS
Model	9.73255	2	4.866275
Residual	47.9118142	97	.493936229
Total	57.6443642	99	.582266305

Number of obs	= 100
F(2, 97)	= 9.85
Prob > F	= 0.0001
R-squared	= 0.1688
Adj R-squared	= 0.1517
Root MSE	= .70281

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age2545	-.6300483	.1866356	-3.38	0.001	-1.000468	-.2596283
age25452	.0130396	.0035623	3.66	0.000	.0059694	.0201098
_cons	9.828285	2.425383	4.05	0.000	5.01457	14.642

According the regression results, the presence of people between the ages of 25 and 45 years old has a significant impact on the availability of car sharing services. Because the coefficient for is positive, the pattern of the regression is convex. In order to illustrate the change in the level of car sharing services as a results of a change in the presence of people between 25 and 45 years, the curve has been plotted in figure 5. The curve shows that the expected positive relationship between the share of residents between 25 and 45 years and the availability of car sharing services is only present for shares of people between 25 and 45 years higher than 24 percent[6]. Furthermore, the explained variance in dependent variable is quite high with an adjusted R-squared of 15 percent.

Figure 5: Plot of presence of car sharing services versus age category 25-45 years



Source: Own processing

Because the interaction between the dummy for highly urbanized municipalities and the age category is also significant at a 10 percent level and the outcome of the F-test is statistically significant too (see appendix II), a model which incorporates this interaction has been runned. There is no evidence of misspecification or heteroskedasticity (see appendix II) so the results can be interpreted.

Source	SS	df	MS
Model	10.4061689	3	3.46872297
Residual	47.2381953	96	.492064534
Total	57.6443642	99	.582266305

Number of obs =	100
F(3, 96) =	7.05
Prob > F =	0.0002
R-squared =	0.1805
Adj R-squared =	0.1549
Root MSE =	.70147

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age2545	-.0018304	.0237488	-0.08	0.939	-.0489714	.0453105
durban1	-4.885918	2.015938	-2.42	0.017	-8.887523	-.8843124
urban1_~2545	.1867558	.06715	2.78	0.007	.0534641	.3200476
_cons	2.373095	.6002104	3.95	0.000	1.181687	3.564503

According the results a very small negative relationship exists between the presence of people between the ages of 25 and 45 years and the availability of car sharing services for non-highly urbanized municipalities. A one percent point increase in the share of people between 25 and 45 years old causes a decrease in the number of shared cars per 100.000 inhabitants by 0.18 percent, keeping other factors fixed. However, for highly urbanized municipalities, an increase of one additional unit in the percentage of people between 25 and 45 years leads to a strong increase of the number of shared cars per 100.000 inhabitants by 18.5 percent. Because the dummy for highly urbanized municipalities is negatively

6 $\frac{d \ln shcarspop}{dage2545} = -0.63 + 0.026age2545 \text{ , } age2545 = 24{,}23$

significant, the expected value of car sharing services is lower in highly urbanized municipalities in the hypothetical situation that the share of people between 25 and 45 years is equal to zero. Furthermore, the explained variance in the dependent variable is equal to 15 percent.

4.1.5. Education

The linear relationship between the presence of higher educated people and the availability of shared cars can be represented by the next equation:

$$\ln shcarspop = f(higheduc) + \varepsilon$$

Because the interaction between the dummy for little urban municipalities and the presence of higher educated people is significant and the outcome of an F-test indicate that this model predicts better compared to the simple model (see appendix II), the interaction has been included in the model. There is no evidence of heteroskedasticity or misspecification of the functional form (see appendix II), so the results of the model can be interpreted.

Source	SS	df	MS		
Model	23.3911579	3	7.79705264	Number of obs =	69
Residual	18.0038347	65	.276982072	F(3, 65) =	28.15
Total	41.3949926	68	.608749891	Prob > F =	0.0000
				R-squared =	0.5651
				Adj R-squared =	0.5450
				Root MSE =	.52629

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
higheduc	.100211	.0109707	9.13	0.000	.078301	.1221209
durban4	4.226876	2.255161	1.87	0.065	-.2769919	8.730743
urban4_educ	-.2446966	.1452716	-1.68	0.097	-.5348241	.0454308
_cons	.3125939	.2321853	1.35	0.183	-.1511122	.7763

According the model, a strong positive and significant relationship is present between the dependent variable and the share of higher-educated people. An increase in the share of higher educated people with one percentage point means an increase in the number of shared cars per 100.000 inhabitants of 10 percent for municipalities which are not little urban, keeping other factors included in the error term constant. For little urban municipalities, an increase by one additional unit in the share of higher educated people leads to a decrease in the availability of car sharing services by 14.5 percent, keeping other factors fixed. Because the dummy for little urban municipalities is positively significant at a 10 percent level, the expected level of car sharing services in the hypothetical situation that the share of higher educated people is equal to zero is higher in little urban municipalities compared to other municipalities. Striking is the extremely high explanatory power of the education level with an adjusted R-squared of almost 55 percent.

4.1.6. Household size

The relationship between the average household size and the availability of car sharing services is non-linear and that's why a quadratic term is added to the following equation:

$$\ln shcarspop = f(avhousehold, avhousehold^2) + \varepsilon$$

There is no evidence of misspecification of the functional form or heteroskedasticity (see appendix II), so the results below can be interpreted.

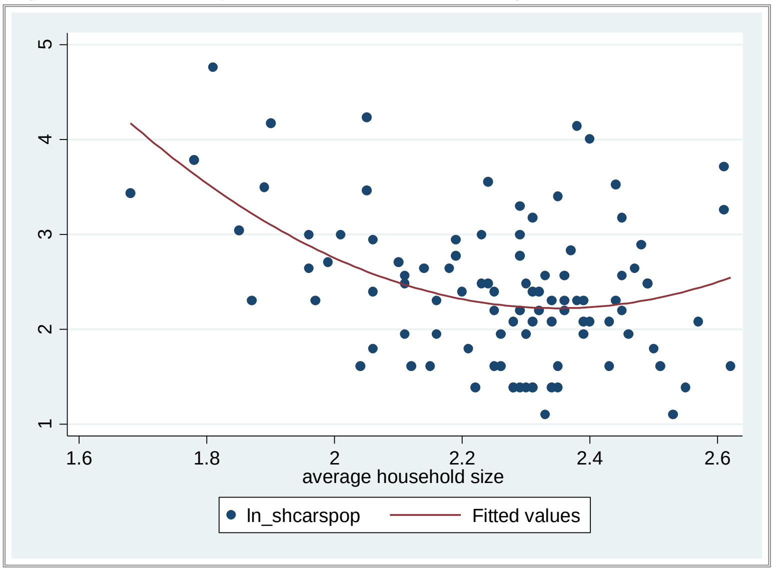
Source	SS	df	MS
Model	11.1419856	2	5.57099281
Residual	46.5023786	97	.479405965
Total	57.6443642	99	.582266305

Number of obs =	100
F(2, 97) =	11.62
Prob > F =	0.0000
R-squared =	0.1933
Adj R-squared =	0.1767
Root MSE =	.69239

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
avhousehold	-20.56095	6.138879	-3.35	0.001	-32.74493	-8.376977
household2	4.37807	1.394701	3.14	0.002	1.609975	7.146165
_cons	26.36125	6.72522	3.92	0.000	13.01355	39.70895

According the regression results, the average household size is significant at a 10 percent level and the coefficient for the squared household size is positive, which means that the pattern of the regression is convex. In the figure below, the function has been plotted to illustrate the change. The figure illustrates a diminishing decline in the level of car sharing services if average household size increases towards a minimum level at an average household size of approximately 2.4[7]. After this point, again a small increase in the level of car sharing services takes place. Furthermore, the explained variance in the dependent variable is quite high with an adjusted R-squared of almost 18 percent.

Figure 6: Plot of presence of car sharing services versus average household size



Source: Own processing

4.1.7. Car ownership

The relationship between the number of residents per private car and the presence of shared cars is non-linear and can be expressed by the next equation:

$$\ln shcarspop = f(carownership, carownership^2) + \varepsilon$$

There is no evidence of misspecification of the functional form or heteroskedasticity according the outcomes of the Ramsey Reset test and Breusch-Pagan test (see appendix II), so we can interpret the results.

[7] $\frac{d \ln shcarspop}{davhousehold} = -20.56 + 8.76 avhousehold\ , avhousehold = 2{,}35$

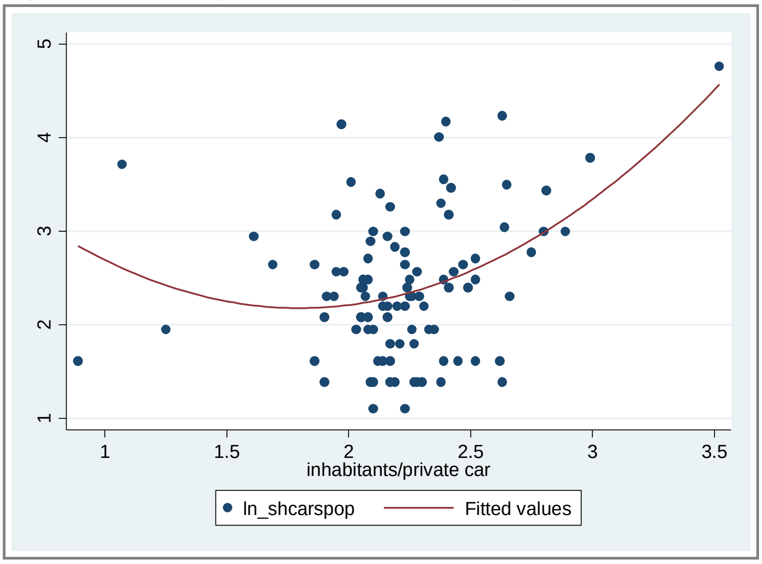
Source	SS	df	MS
Model	9.57938542	2	4.78969271
Residual	48.0649788	97	.495515245
Total	57.6443642	99	.582266305

Number of obs =	100
F(2, 97) =	9.67
Prob > F =	0.0001
R-squared =	0.1662
Adj R-squared =	0.1490
Root MSE =	.70393

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
carownership	-2.904369	1.064227	-2.73	0.008	-5.016564	-.7921736
carownersh~2	.8072599	.2414881	3.34	0.001	.3279728	1.286547
_cons	4.789668	1.192367	4.02	0.000	2.42315	7.156186

According the regression results, car ownership is significant at a 10 percent level and the coefficient for the squared car ownership is positive, which means that the pattern of the regression is convex. In figure 7, the curve has been plotted and an increasing positive relationship has been showed from a minimum level of car sharing services at a degree of car ownership of approximately 1.8 inhabitants per private car[8]. This means that the expected negative relationship between the number of private cars and the presence of car sharing services is valid for values of car ownership higher than 1.8. Also the explanatory power of car ownership is high with an adjusted R-squared of approximately 15 percent.

Figure 7: Plot of presence of car sharing services versus car ownership



Source: Own processing

4.1.8. Income

The linear relationship between average disposable income and the availability of shared cars can be represented by the next equation:

$$\ln shcarspop = f(\ln avincome) + \varepsilon$$

The Ramsey Rest test and the Breusch-Pagan test indicate that there is no evidence of respectively functional form misspecification and heteroskedasticity, so the results can be interpreted.

8 $\frac{d \ln shcarspop}{dcarownership} = -2.9 + 1.62 carownership \text{ , } carownership = 1.79$

Source	SS	df	MS		Number of obs =	100
					F(1, 98) =	2.87
Model	1.63856854	1	1.63856854		Prob > F =	0.0936
Residual	56.0057957	98	.571487711		R-squared =	0.0284
					Adj R-squared =	0.0185
Total	57.6443642	99	.582266305		Root MSE =	.75597

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_avincome	1.293959	.7641729	1.69	0.094	-.2225173	2.810435
_cons	-1.22119	2.148334	-0.57	0.571	-5.484488	3.042109

According the results, there exists a positive and significant relationship between the average disposable income and the availability of car sharing services. If average income increases with one percent, the number of shared cars per 100.000 inhabitants increases with 1.3 percent, holding other factors included in the error term constant. However, the explanatory power of the independent variable is low with an adjusted R-squared of almost 2 percent.

4.1.9. Resume

Almost all indicators are significant correlated with the supply of car sharing services as expected according the hypothesis. Especially, the presence of higher-educated has a strong single positive impact on the availability of car sharing services. Only the average distance to train stations and the modal split of cycling on short distances do not show a single significant relationship with the availability of car sharing services.

Interesting is that the impact of some factors differs geographically, because some interactions of the continuous variables with the dummies for urbanity or Randstad municipalities are strongly significant. For highly or strong urbanized municipalities, expected relationships between indicators such as local accessibility by public transport and presence of people between 25 and 45 years and the dependent variable are stronger, while expected relationships between indicators such as presence of higher educated people and distance to transfer stations and the dependent variable are weaker or even not valid for moderate or little urban municipalities. According the restricted models, the Randstad and other parts of the Netherlands differ with respect to the impact of national accessibility by public transport and the proximity of transfer stations on the availability of car sharing services, these relationships are much stronger for Randstad municipalities.

There can also be concluded that not all expected relationships are strictly linear. For example, positive relationships between local and regional accessibility by public transport, the number of inhabitants per private car and the share of people between the ages of 25 and 45 years on the one hand and the availability of car sharing services on the other hand are only valid from a certain minimal presence of those explanatory indicators and have an increasing positive impact from here. Conversely, the average household size has a declining negative impact on the presence of car sharing services towards a minimum level at a household size of more than two persons. From here, there exists no negative relationship anymore according the restricted model.

However, the availability of car sharing services does probably not depend on separate factors in practice, but on a lot of factors, which affect the presence of shared cars together. That’s why in the next sections the common impact of groups of variables will be estimated in order to prevent omitted variable bias.

4.2. Spatial characteristics model

In this section, the impact of the common spatial characteristics will be estimated in order to explain the impact of the living area on the supply of car sharing services. The indicators in the categories public transport, density and cycling represent the explanatory variables in the spatial characteristics model. Section 4.2.1 presents the results. In the first model, the impact of all spatial linear indicators has been examined by using a stepwise regression. In the second model, also non-linear terms have been included by ordinary least squares regression.

4.2.1. Results

Spatial characteristics model 1

The relationship between different living area characteristics with population density as indicator for density and the availability of car sharing services can be represented by the next equation:

$$\ln shcarspop$$
$$= f(\ln avdistrain\,, \ln avdistransf\,, avaccpt15, \ln avaccp30\,, avaccpt90, \ln cyclshortdis, \ln popdens\,,$$
$$drandstad) + \varepsilon$$

The Ramsey Reset test and Breusch-Pagan test indicate that there is no evidence of respectively functional form misspecification and heteroskedasticity (see appendix II), so we can interpret the results below.

```
                      begin with full model
p = 0.6246 >= 0.1000  removing ln_avdistrain
p = 0.2510 >= 0.1000  removing avaccpt15
p = 0.1673 >= 0.1000  removing ln_popdens
p = 0.3095 >= 0.1000  removing ln_avaccpt30
p = 0.1320 >= 0.1000  removing drandstad
```

Source	SS	df	MS
Model	15.2928149	3	5.09760496
Residual	42.3515493	96	.441161972
Total	57.6443642	99	.582266305

Number of obs	= 100
F(3, 96)	= 11.55
Prob > F	= 0.0000
R-squared	= 0.2653
Adj R-squared	= 0.2423
Root MSE	= .6642

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_cyclsho~s	.9320577	.4002856	2.33	0.022	.1374971	1.726618
ln_avdistr~f	-.2215961	.1066837	-2.08	0.040	-.4333615	-.0098307
avaccpt90	.0001811	.0000356	5.09	0.000	.0001105	.0002517
_cons	-1.213723	1.480092	-0.82	0.414	-4.151683	1.724237

According the results, the average distance to transfer stations, the average accessibility by public transport within 90 minutes and the share of cycling in the modal split on short distances have a significant impact on the availability of car sharing services if more spatial characteristics are included in the model. Remarkably, some factors which had a single significant impact in the restrictive models, such as the average accessibility by public transport within 15 and 30 minutes and population density, have no longer a significant impact on the dependent variable. On the other hand, the modal split of cycling on short distances had no single significant impact on the dependent variable, but the variable is significant in combination with other spatial characteristics. A higher modal split of cycling means a higher level of car sharing services, while a higher distance to transfer stations means a little bit lower level of car sharing services, keeping other factors constant. Finally, an increase in the average accessibility within 90 minutes by public transport by one additional inhabitant means a very small increase in the availability of car sharing services, holding other factors fixed. The model has an explanatory value of almost 25 percent.

Spatial characteristics model 2
In this model, the relationship between spatial characteristics and the presence of car sharing services is measured by also incorporating non-linear terms. The model has been estimated by using ordinary least squares regression. The best fitting living area variables with the most consistent impact have been represented in the next equation:

$$\ln shcarspop = f(\ln avdistransf\ , avaccpt15, \ln avaccp30\ , avaccpt90, \ln cyclshortdis, \ln popdens\ , \\ drandstad, rstd\_popdens, rstd\_transf, rstd\_pt90, urban2\_pt15, urban3\_transf) + \varepsilon$$

The results meet the conditions of homoskedasticity and are based on a very strong functional form specification, according the outcomes of the Breusch-Pagan test and the Ramsey Reset test (see appendix II).

Source	SS	df	MS
Model	23.6833638	7	3.38333768
Residual	33.9610005	92	.369141309
Total	57.6443642	99	.582266305

Number of obs =	100
F(7, 92) =	9.17
Prob > F =	0.0000
R-squared =	0.4109
Adj R-squared =	0.3660
Root MSE =	.60757

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_cyclsho~s	1.167445	.3863815	3.02	0.003	.4000581	1.934832
avaccpt90	.0001352	.0000374	3.62	0.000	.000061	.0002094
ln_avdistr~f	-.152942	.1079724	-1.42	0.160	-.3673845	.0615006
ln_popdens	.2138476	.0903907	2.37	0.020	.0343238	.3933714
avaccpt15	.0172492	.0103236	1.67	0.098	-.0032542	.0377527
urban2_pt15	-.0559034	.0124186	-4.50	0.000	-.0805679	-.0312389
urban3_tra~f	-.1250463	.0676665	-1.85	0.068	-.2594377	.0093452
_cons	-3.345542	1.566684	-2.14	0.035	-6.457112	-.2339718

The first things to note are the high explained variance of almost 37 percent compared to the model with only linearity's and the larger number of significant variables. The modal split of cycling and the national accessibility by public transport have more or less the same impact as in the model with only linear variables. However, in the new model also population density is statistically significant at a 10 percent level and has a small positive impact on the availability of car sharing services. Moreover, the interactions of moderate urban municipalities with distance to important railway stations and strong urban municipalities with local public transport are statistically significant. The significance of the first interaction means that the positive impact of proximity of transfer stations on the availability of car sharing services is stronger for moderate urban municipalities compared to other municipalities. The negative significance of the second interaction means that local accessibility by public transport has a small negative impact on the presence of shared cars, while local accessibility by has a positive impact on the availability of car sharing services in municipalities with another degree of urbanity. Other spatial indicators, such as the degree of regional accessibility by public transport or Randstad location do not have a significant impact on the availability of car sharing services if the impact of the common spatial characteristics is estimated.

4.2.2. Resume

A clear picture emerges if only the impact of the spatial environment on the presence of shared cars will be examined. It can be concluded that the proximity of important transfer stations and the modal split of cycling have a positive significant impact on the availability of car sharing services if only spatial characteristics have been taken into account. Also supra-regional/national accessibility by public transport has a positive impact on the offering of car sharing services. However, if the model has been extended and when corrected for differences in urbanity, also population density and local accessibility by public transport have a positive impact on the supply of car sharing services. Furthermore, the relationship between proximity of important railway stations for moderate urban municipalities, while the impact of local accessibility by public transport on the use of car sharing is negative for strong urban municipalities.

Based on the examination of the common impact of spatial indicators on the use of car sharing services, it seems to be that general spatial conditions for sustainable mobility are also important for the use of car sharing services. There seems to be a positive relationship between the use of sustainable modes such as cycling and public transport, because indicators as the modal split of cycling on short distances, proximity of important railway stations and local and national accessibility by public transport are positively significant, which confirms the theoretical expectations that they are complementary to each other. Moreover, population density seems to be an essential condition for offering car sharing services, because probably a certain support is needed to offer car sharing services in a profitable way, which corresponds to the interaction between land use and transport in the transport land use feedback cycle (see section 2.4) (Wegener & Fürst, 1999). Based on spatial conditions, offering car sharing services seems to be more successful in bigger cities and metropolitan regions, because the public transport network is more extensive and densities are often higher.

4.3. Customer characteristics model

Taking only characteristics of population into account may be helpful for identifying new potential clients. In subsection 4.3.1, four models are presented. In the first and second model, only linear terms have been included, but the models differ regarding the inclusion of education. In the third and the fourth model also non-linear effects have been included. The models again differ from each other regarding the inclusion of education. In subsection 4.3.2, a consideration of the results and an interpretation are given.

4.3.1. Results

Customer characteristics model 1

The relationship between the various customer characteristics on the one hand and the number of shared cars available per 100.000 inhabitants on the other hand can be represented by the next equation:

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, \ln avincome\ , carownership) + \varepsilon$$

According the Ramsey Reset test and the Breusch-Pagan test, there is no evidence of respectively functional form misspecification and heteroskedasticity (see appendix II), so the results from the regression can be interpreted.

```
                         begin with full model
p = 0.7845 >= 0.1000  removing avhousehold
p = 0.4159 >= 0.1000  removing age2025
p = 0.1154 >= 0.1000  removing carownership

      Source |       SS       df       MS              Number of obs =      69
-------------+------------------------------           F(  3,    65) =   29.39
       Model |  23.8284224     3  7.94280747           Prob > F      =  0.0000
    Residual |  17.5665702    65  .270254926           R-squared     =  0.5756
-------------+------------------------------           Adj R-squared =  0.5560
       Total |  41.3949926    68  .608749891           Root MSE      =  .51986

------------------------------------------------------------------------------
ln_shcarspop |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    higheduc |   .0697131   .0137869     5.06   0.000     .0421787    .0972474
     age2545 |   .0744499   .0273528     2.72   0.008     .0198227    .1290772
 ln_avincome |   2.304723    1.03895     2.22   0.030      .229797    4.379649
       _cons |  -7.472396   3.251216    -2.30   0.025    -13.96552   -.9792695
------------------------------------------------------------------------------
```

According the results, the average income, the share of people in the category 25-45 years and the share of higher educated people have a positive and significant impact on the availability of car sharing services if they have been taken into account with other customer characteristics. Especially, the share of higher-educated people is strongly significant, because of its very low p-value. An increase in the share of higher educated people with one unit means an increase in the availability of car sharing services by almost 7 percent, holding other factors fixed. The variables which represents the share of people between the ages of 20 and 25, the level of car ownership and the average household size have not a significant impact on the dependent variable in combination with other customer characteristics as explanatory variables.

Striking is the high explanatory power of the three significant variables, with an adjusted R-squared of almost 56 percent. Presumably, this due to the inclusion of the variable for higher education, because this variable also has a strong explanatory power in the restricted models. That's why it is interesting to see the impact on the explanatory power of the model if the variable for higher education is not included in the model. Moreover, data about education are only present for the 69 municipalities in the sample with more than 30.000 inhabitants. Therefore, a second regression will be performed.

Customer characteristics model 2

The relationship between customer characteristics without the share of higher-educated people on the one hand and the dependent variable for the availability of car sharing services on the other hand can be expressed by the next equation:

$$\ln shcarspop = f(age2025, age2545, avhousehold, \ln avincome\ , carownership) + \varepsilon$$

According the outcomes of the Ramsey Reset test and the Breusch-Pagan test, there is no evidence of respectively misspecification of the functional form or heteroskedasticity (see appendix II), so the results below can be interpreted.

```
                         begin with full model
p = 0.6938 >= 0.1000  removing avhousehold

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  4,    95) =    9.28
       Model |  16.1989524     4  4.04973809           Prob > F      =  0.0000
    Residual |  41.4454118    95  .436267493           R-squared     =  0.2810
-------------+------------------------------           Adj R-squared =  0.2507
       Total |  57.6443642    99  .582266305           Root MSE      =  .66051

------------------------------------------------------------------------------
ln_shcarspop |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     age2025 |    .083879   .0446134     1.88   0.063    -.0046898    .1724478
     age2545 |   .0740206    .026428     2.80   0.006     .0215545    .1264868
 ln_avincome |   4.168169    .851427     4.90   0.000     2.477873    5.858466
carownership |   .4184173   .2180987     1.92   0.058    -.0145635     .851398
       _cons |  -12.62643   2.804668    -4.50   0.000     -18.1944   -7.058459
------------------------------------------------------------------------------
```

According the results, the share of population between 25 and 45 years and the average disposable income have again a positive and significant impact on the availability of car sharing services. However, also the share of population between 20 and 25 years and the number of people per private car are now positively significant. Only the average household size is not significant in combination with other customer characteristics.

If education is not present in the model, the explanatory variables explain only 25 percent of the variance in the dependent variable. This is an indication that the large explanatory power of the previous model is due to the inclusion of this variable.

Customer characteristics model 3
In this model, the relationship between customer characteristics and car sharing has been measured by also including non-linear terms. This relationship is represented by the next equation:

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, household2, carownership, durban4, urban4\_car) + \varepsilon$$

Because the functional form is very well specified according the Ramsey Reset test and there is no evidence of heteroskedasticity (see appendix II), it is possible to interpret the results below.

Source	SS	df	MS
Model	29.5904214	8	3.69880267
Residual	11.8045713	60	.196742854
Total	41.3949926	68	.608749891

Number of obs	= 69
F(8, 60)	= 18.80
Prob > F	= 0.0000
R-squared	= 0.7148
Adj R-squared	= 0.6768
Root MSE	= .44356

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age2025	-.2278205	.0548356	-4.15	0.000	-.3375081	-.1181329
age2545	.0714585	.0210306	3.40	0.001	.0293911	.113526
higheduc	.0758551	.0136729	5.55	0.000	.0485052	.1032051
avhousehold	-29.54667	8.590756	-3.44	0.001	-46.73074	-12.3626
household2	6.476026	1.881707	3.44	0.001	2.712051	10.24
urban4_car	-5.015504	1.867549	-2.69	0.009	-8.751158	-1.279851
carownership	.1775561	.1675931	1.06	0.294	-.15768	.5127922
durban4	10.69186	3.817508	2.80	0.007	3.055702	18.32801
_cons	33.36147	10.22286	3.26	0.002	12.9127	53.81024

The first thing to notice is the very high explanatory power of the independent variables with an adjusted R-squared of almost 68 percent. As in the previous models, the variables for presence of higher-educated people and people between 25 an 45 years old are strongly significant at a significance level of 10 percent and have a positive impact on the availability of car sharing services. Also the presence of younger people is strongly significant, but this indicator has a negative impact on the dependent variable according this model. This is striking according theoretical expectations and also according the results of the restricted models in section 4.1. The squaring of the variable for average household size leads to a strong significance of this variable. Because the coefficient is positive, the curve is convex and there exists a diminishing decline, which means that an increase in the average household size leads to a decrease in the presence of car sharing services, but this decrease is smaller for a larger household size. From an average household size of approximately 2.3

persons, there exists no negative relationship anymore[9]. There exists also a negative relationship between the number of inhabitants per private cars and the availability of car sharing services for little urban municipalities, which is striking because it is not according theoretical expectations. For municipalities with another degree of urbanity, the expected positive relationship between the number of inhabitants per private car and the presence of car sharing services still exists. Finally, in the model with non-linearities, the variable for income is not significant anymore.

Customer characteristics model 4
In order to increase the number of observations, also a model with non-linearties without the inclusion of education has been calculated. The best fitting independent variables are present in the next equation:

$$\ln shcarspop = f(age2545, avhousehold, household2, \ln avincome) + \varepsilon$$

Because there is no evidence of misspecification or heteroskedasticity (see appendix II), the regression results below are consistent and unbiased.

Source	SS	df	MS		
Model	19.2994746	4	4.82486866	Number of obs =	100
Residual	38.3448896	95	.403630417	F(4, 95) =	11.95
				Prob > F =	0.0000
				R-squared =	0.3348
				Adj R-squared =	0.3068
Total	57.6443642	99	.582266305	Root MSE =	.63532

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age2545	.0743869	.0271851	2.74	0.007	.0204178	.1283561
avhousehold	-23.95568	5.886991	-4.07	0.000	-35.64283	-12.26852
household2	5.258942	1.329097	3.96	0.000	2.62035	7.897534
ln_avincome	3.80332	.8460133	4.50	0.000	2.123771	5.482869
_cons	16.90601	6.975705	2.42	0.017	3.057483	30.75453

Again, it is remarkably that the explanatory power of the model is much lower if education is not included with an adjusted R-squared of almost 31 percent. Furthermore, all variables are strongly significant. The presence of people between the ages of 25 and 45 has again a positive impact on the dependent variable. In contrast with the previous model, the level of income affects the availability of car sharing services in a positive way. Finally, the relationship between household size and the dependent variable can be characterized as one of diminishing decline until a minimum level of car sharing services at an average household size of approximately 2.2 persons[10]**.**

4.3.2. Resume

The common customer characteristics explain much of the variance in the availability of car sharing services with a maximum explanatory power of approximately 68 percent. However, this is mainly due to the inclusion of the variable for the presence of higher educated people, because the explanatory power of the first and third customer characteristics model is much higher compared to the power of the second and fourth model. So, it can be concluded that the presence of higher educated people has a strong positive impact on the availability of car sharing services. Also the presence of people in the age category between 25 and 45 years

---

9 $\frac{d \ln shcarspop}{davhousehold} = -29.55 + 12.96avhousehold \text{ , } avhousehold = 2.28$

10 $\frac{d \ln shcarspop}{davhousehold} = -23.96 + 10.72avhousehold \text{ , } avhousehold = 2.24$

has a positive impact on the dependent variable, because this variable remains significant in all of the models at a significance level of 10 percent. Furthermore, the average household size has a declining negative and significant impact on the presence of car sharing services after squaring until the minimum is reached at an average household size of approximately 2.3 persons.
The other customer characteristics are sometimes significant, but sometimes not. Income has a positive impact in three of the four models, but is insignificant in the model with the highest explanatory power. The explanatory power of the other variables is probably higher in this model and adding income has no added value anymore. Car ownership is positively significant in two models which means that the higher the number of people per private car, the higher the presence of shared cars in these cases. The direction of the relationship which is according theoretical expectations is valid for most municipalities, except for little urban municipalities. For these municipalities, a negative significant relationship between the number of inhabitants per private car and the supply of car sharing services exists, according the third model, which is surprising and in contrast with theoretical expectations. A possible explanation could be that the little urban municipalities which have been included in our model are not fully representative for all little urban municipalities, because they belong to the hundred municipalities with the highest number of shared cars per or that the number of little urban municipalities in the sample is too small.

Finally, the variable which measures the presence of younger people between 20 and 25 years old, which can be considered as potential customers, is also significant in two models. However, in the second model, this variable has still a small positive impact on the level of car sharing services, but in the third model the variable has a negative impact on the dependent variable. So there is no evidence of a clear positive impact of this variable based on the regressions with customer characteristics.

Based on the analyses of these regressions, it seems to be that customers characteristics are very important for offering car sharing services in a profitable way. This confirms the theoretical expectations that especially a certain group of people with university or college degrees, smaller household sizes, higher incomes, which do not possess a car and are between the ages of 25 and 45 years seems to be potentially interested in car sharing services. But more important, this allows for a targeted approach of these types of people by suppliers of car sharing services. Based on the customer characteristics models, these conditions with respect to potential clients seems to affect the possibilities for offering car sharing services regardless of geographical conditions, such as urbanity degree or Randstad location. However, it may be that the outlined type of customer lives more often in cities, because of his preferences (Storper & Manville, 2006), but the outcomes of these models provide little evidence for this.

4.4. Full model

In order to estimate the common effect of indicators with respect to people and the spatial environment on the presence of shared cars, some models which include variables of both categories are composed. In subsection 4.3.1., the results of the models will be presented. Again in the first two models, only linear terms have been included. The models differ from each other with respect to the inclusion of education as explanatory variable. The third and the fourth model allow also for non-linear terms and differ also from each other with respect to the inclusion of education. In subsection 4.3.2., an explanation and consideration of the results will be given.

4.4.1. Results

Full model 1

The relationship between the explanatory variables and the dependent variable can be estimated by using the next equation:

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, age2025, age2545, higheduc, avhousehold, \ln avincome, carownership, drandstad) + \varepsilon$$

The model fulfills the conditions with respect to homoskedasticity and functional form specification (see appendix II), so we can interpret the results below.

```
                      begin with full model
p = 0.8902 >= 0.1000  removing ln_avdistransf
p = 0.8688 >= 0.1000  removing ln_cyclshortdis
p = 0.7131 >= 0.1000  removing avhousehold
p = 0.5069 >= 0.1000  removing ln_avdistrain
p = 0.5137 >= 0.1000  removing ln_avincome
p = 0.3782 >= 0.1000  removing drandstad
p = 0.3361 >= 0.1000  removing avaccpt90
p = 0.2633 >= 0.1000  removing age2545
p = 0.1599 >= 0.1000  removing carownership
```

Source	SS	df	MS
Model	25.7689642	5	5.15379284
Residual	15.6260284	63	.248032197
Total	41.3949926	68	.608749891

Number of obs	= 69
F(5, 63)	= 20.78
Prob > F	= 0.0000
R-squared	= 0.6225
Adj R-squared	= 0.5926
Root MSE	= .49803

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_popdens	.2129512	.0846116	2.52	0.014	.0438684	.3820339
age2025	-.058821	.03398	-1.73	0.088	-.1267247	.0090827
higheduc	.0941032	.0126131	7.46	0.000	.0688979	.1193085
ln_avaccpt30	-.1406579	.077441	-1.82	0.074	-.2954113	.0140955
avaccpt15	.0250766	.0093403	2.68	0.009	.0064115	.0437417
_cons	-.2823081	.5104612	-0.55	0.582	-1.302383	.7377672

According the results in the model, education has again a strong positive impact on the availability of car sharing services. Also, population density and the average accessibility within 15 minutes by public transport have a positive impact on the dependent variable if both spatial and customer characteristics have been taken into account. Furthermore, the share of people between the ages of 20 and 25 years and the accessibility by public transport within 30 minutes both have a significant impact on the presence of shared cars, but in a negative way. This is surprising, because the theory assumes a positive impact of these explanatory variables. All other explanatory variables are not significant in this model. Almost 60 percent of the variance in the dependent variable is explained by the explanatory variables.

Full model 2

The next equation represents the best fitting variables if education has not been included as in dependent variable:

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, age2025, age2545, avhousehold, \ln avincome, carownership, drandstad) + \varepsilon$$

However, it is not possible to interpret the outcomes of the regression, because the condition of functional form specification has not been fulfilled, so results are probably inconsistent and biased.

Full model 3
In order to correct for non-linear effects, also a model which includes interactions and squares has been estimated. The next equation presents the best fitting variables with respect to the variance in the number of shared cars per 100.000 inhabitants:

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, household2, avaccpt15, \ln popdens, urban1\_pt15, urban2\_pt15, urban4\_car, rstd\_car, rstd\_popdens, rstd\_ag2545) + \varepsilon$$

According the Ramsey Reset test and the Breusch-Pagan test, the model is well-specified and there is no evidence of heteroskedasticity (see appendix II), so the results can be interpreted.

Source	SS	df	MS		
Model	34.5827176	14	2.47019412	Number of obs =	69
Residual	6.81227501	54	.126153241	F(14, 54) =	19.58
				Prob > F =	0.0000
Total	41.3949926	68	.608749891	R-squared =	0.8354
				Adj R-squared =	0.7928
				Root MSE =	.35518

ln_shcarspop	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_popdens	.582198	.1221538	4.77	0.000	.3372943	.8271018
avaccpt15	.0371536	.0093657	3.97	0.000	.0183764	.0559308
age2025	-.1828815	.0484908	-3.77	0.000	-.2800997	-.0856634
age2545	-.0328212	.0308241	-1.06	0.292	-.0946197	.0289774
avhousehold	-14.40167	7.600203	-1.89	0.063	-29.63916	.835822
household2	3.166375	1.665967	1.90	0.063	-.1736881	6.506439
higheduc	.0901277	.0116826	7.71	0.000	.0667054	.11355
carownership	.6950185	.2482656	2.80	0.007	.1972761	1.192761
urban1_pt15	-.0373794	.011922	-3.14	0.003	-.0612816	-.0134773
urban2_pt15	-.0409878	.01007	-4.07	0.000	-.0611769	-.0207987
urban4_car	.3595493	.096358	3.73	0.000	.1663632	.5527353
rstd_car	-.6017982	.274387	-2.19	0.033	-1.151911	-.0516854
rstd_popdens	-.3131928	.1273247	-2.46	0.017	-.5684635	-.0579221
rstd_age2545	.1275313	.0353867	3.60	0.001	.0565852	.1984773
_cons	13.09237	9.128538	1.43	0.157	-5.209245	31.39399

The first striking thing is the very high explanatory power of this model with an adjusted R-squared of 79 percent. Only twenty percent of the variance in the number of shared cars per 100.000 inhabitants has not been explained by the variables in our model.

Again, the presence of higher educated people is strongly significant at a 10 percent level and has a positive impact on the dependent variable. Average household size has a diminishing negative impact on the presence of shared cars until a minimum presence has been reached at an average household size of approximately 2.3 persons[11]. The presence of younger people between 2 and 25 years is also strongly significant, but has a negative impact on the availability of car sharing services which is somewhat different than expected.

For other explanatory variables, the impact of them on car sharing services differs geographically. Population density and the number of inhabitants per private car have a significant positive impact on the availability of car sharing services, but the magnitude of this impact is much smaller for Randstad municipalities. Moreover, the positive impact of

[11] $\frac{d \ln shcarspop}{davhousehold} = -14.40 + 6.34 avhousehold\ , avhousehold = 2.27$

the number of inhabitants per private car is bigger in little urban municipalities compared to municipalities with another urbanity. This means that the negative relationship between availability of private cars and shared cars is stronger in this type of municipalities.

There is also a significant positive relation between local accessibility by public transport and the presence of car sharing services. However, a very small negative relationship exists between local accessibility and car sharing in highly urbanized and strong urban municipalities according the outcomes of this model. Furthermore, for Randstad municipalities, a strong positive and significant relationship exists between presence of people between the ages of 25 and 45 years and presence of shared cars, but a small negative relationship between these variables exists for non-Randstad municipalities.

Finally, other indicators that were significant in previous models, such as level of income, proximity to transfer stations, regional and national accessibility by public transport and the modal split of cycling at short distances have no significant impact anymore in this model. Probably because these factors have too little added explanatory value in comparison with the significant variables.

Full model 4

In order to estimate the relationship between explanatory indicators and the presence of shared cars for hundred municipalities, a last model without the inclusion of education as explanatory variable has been estimated. The relationship between the best fitting explanatory variables and the dependent variable can be estimated by using the next equation:

$$\ln shcarspop = f(age2545, avhousehold, household2, avaccpt15, \text{avaccp90}, \text{carownership}, \ln popdens, \ln cyclshortdis, urban2\_pt15, urban4\_car, urban1\_ag2545) + \varepsilon$$

According the Ramsey Reset there is no evidence of misspecification, but the Breusch Pagan test indicates evidence of heteroskedasticity (see appendix II). In order to fulfill the condition of homoskedasticity, a regression with robust standard errors has been performed.

```
Linear regression                               Number of obs =      100
                                                F( 11,    88) =    15.24
                                                Prob > F      =   0.0000
                                                R-squared     =   0.5544
                                                Root MSE      =   .54026
```

ln_shcarspop	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_popdens	.2289388	.1066855	2.15	0.035	.0169239	.4409538
avaccpt15	.0187804	.0106827	1.76	0.082	-.0024492	.0400099
age2545	.0245735	.018339	1.34	0.184	-.0118713	.0610184
avhousehold	-15.21479	5.7527	-2.64	0.010	-26.64708	-3.782511
household2	3.050066	1.339064	2.28	0.025	.388958	5.711174
urban1_~2545	-.0322933	.010759	-3.00	0.003	-.0536745	-.0109121
carownership	.1998708	.1788491	1.12	0.267	-.1555541	.5552958
urban2_pt15	-.0585468	.0133888	-4.37	0.000	-.0851542	-.0319393
urban4_car	.2593506	.105356	2.46	0.016	.0499776	.4687236
avaccpt90	.0001849	.0000385	4.81	0.000	.0001085	.0002614
ln_cyclsho~s	1.102277	.3444623	3.20	0.002	.4177302	1.786823
_cons	13.81748	6.69527	2.06	0.042	.5120342	27.12292

Again, the model above without the inclusion of education has a much lower explanatory power with an R-squared of 55 percent compared to the last model in which education has been included. Average household size has the same declining negative and significant relationship with car sharing as in previous model until a minimum level of shared cars has been reached at an average household size of approximately 2.5 persons[12]. Population density, national accessibility by public transport and the modal split of cycling on short distances have also a positive and significant impact on the availability of car sharing services.

The strength of other relationships differs geographically. Again, a small negative and significant relationship between local accessibility by public transport and the presence of shared cars exists for strong urban municipalities, while a small positive relationship is present between these variables in other types of municipalities. The number of inhabitants per car has a significant and positive impact on the availability of car sharing services and the magnitude of this positive impact is even higher for little urban municipalities, which means the higher the number of private cars, the lower the number of shared cars.

Finally, a positive relationship exists between the presence of people between the ages of 25 and 45 years and the presence of shared cars, except for highly urbanized municipalities for which a negative and significant relationship exists.

4.4.2. Resume

The significant independent variables in the full models explain much of the variance in the level of car sharing services. As in previous sections, the models which include the presence of higher educated people have a much higher explanatory power. This means that there is again strong evidence for a positive impact of the presence of people with college or university degrees on the level of car sharing services.

Also other customer indicators have a significant impact, except for the level of income, but not always in the expected way. The presence of younger people between 20 and 25 years, which can be considered as potential car sharers has a negative impact in the first and third full model if a lot of significant variables have been included. A possible interpretation for the lack of a clear positive connection is that it is about potential car sharing customers. Some suppliers of car sharing services, such as the Dutch market leader Greenwheels apply an age restriction to the use of car sharing for people younger than 24 years, due to the higher risk of injury and accidents in this group (Greenwheels, 2013; KpVV, 2013). But it does not alter that a high presence of younger people may be positive for the offering for car sharing services in the future, because it seems that younger people care less about having a private car (Kuhnimhof *et al.*, 2012).

The presence of people between 25 and 45 years has no significant impact in the model with only linear terms, but after interactions have been added, there is evidence of a stronger positive impact of this presence on car sharing for Randstad municipalities, but not for municipalities outside this area. In the fourth model, there is evidence of a small negative effect on the presence of shared cars for highly urbanized municipalities compared to municipalities with another degree of urbanity. However, based on the analyses of the full models there is insufficient evidence of a general positive impact of the presence of people

12 $\frac{d \ln shcarspop}{davhousehold} = -15.21 + 6.1 avhousehold$, $avhousehold = 2.49$

between the ages of 25 and 45 years on the availability of car sharing services regardless of geographical factors.

Car ownership and average household size have impact on the availability of car sharing services in the expected way. Both variables became significant in the models with non-linearities. There is evidence of a negative relationship between the presence of private cars and the availability of car sharing services. This relation is stronger for little urban municipalities and according the third model somewhat less strong for Randstad municipalities. The relationship between can be characterized as one of diminishing decline until a minimum level of car sharing services at household sizes larger than two persons. This means that especially households without children are (potentially) interested in car sharing services.

With respect to spatial characteristics, there is car evidence of a positive impact of population density on the presence of car sharing services. Also local accessibility by public transport seems to be an important condition for offering car sharing services, although this impact is less strong or even negative for highly urbanized and strong urban municipalities. A positive relationship between the national accessibility by public transport and the modal share of cycling on the one hand and the presence of car sharing services exists only in the fourth model, but they have too little explanatory value to incorporate them in the third model. Surprisingly, regional accessibility by public transport is significant in the first model, but in a negative way. A possible interpretation is that car sharing and public transport compete especially with each other at regional movements, because according Shaheen *et al.* (1998) using car sharing services is most attractive for medium distances in a region if fast public transport connections are lacking. If good regional public transport connections are already present, offering car sharing and so the demand for car sharing services may be lower. However, the variable is only significant in the first model, thus probably a clear impact is lacking. The average distance to railway stations does not have any significant impact at all in the different models. So there is no clear evidence of a general positive relationship between the availability of good public transport connections and the presence of car sharing services, based on the full models.

It can be concluded that if the impact of all indicators has been examined, especially factors with respect to customers have decisive influence. At the end, it makes probably more sense to offer car sharing services based on the targeting of customer groups rather than targeting based on area.

5. Discussion and assessment

In the previous chapter, the impact of several indicators on the availability of car sharing services have been tested. In this chapter, the results and have been analyzed and assessed. Section 5.1 starts with a general discussion and analysis of the different findings from the previous chapters. In section 5.2, the different hypotheses will be accepted or rejected, based on the discussion and interpretation of the results.

5.1. Discussion

Almost all examined indicators have a significant impact on the level of car sharing services in the way that is expected in one of the models. Because the offering of traditional car sharing services is highly demand driven, it is expected that these indicators are also important explanatory factors for the demand to car sharing services. Only the distance to train stations seems to have no influence on the presence of car sharing, but the proximity to important transfer stations does have impact on the supply of car sharing services in some of the models. The use of bikes as mode of transport, measured by the modal split of cycling on short distances, also shows no single significant relationship with the presence of car sharing services in the restricted models, but have impact in some multiple regression models. For each of the hypothesis, there seems to be at least any evidence.

However, because the different explanatory indicators have also impact on each other, only the indicators with the highest added explanatory power remain significant if their common impact have been tested. These indicators probably explain the demand to car sharing services in practice.

Customer indicators

If a comparison has been made between the models with only spatial characteristics and the models with customer characteristics, the customer characteristics models have much more explanatory power. Also in the full model, customer indicators are more often significant.

Especially, the presence of people with a college or university degree is strongly significant in all the models in which this factor has been included and explains in all of the models a large part of the variance in the supply of car sharing services. After squaring, also average household size has a declining negative impact on the presence of car sharing services in all the models. However, if the average household size is larger than two persons, no further decrease in the use of car sharing services takes place. This probably means that especially single households are (potentially) suitable for using car sharing services and to a lesser extent couples without children. According Beuningen *et al.* (2012), almost all households with children possess a car, because they really need it for combining and participating in all kind of activities. Probably, car sharing services have little added value for them. The demonstrated negative relationship between the number of private cars and the presence of car sharing services corresponds to this. There is also some evidence that the negative relationship between the presence of private cars and car sharing services is stronger for little urban municipalities and less strong for Randstad municipalities, but because not all the models produce these results, it is hard to draw firm conclusions about it.

According the customer characteristics models, the presence of people in the age category 25-45 years has a strong positive relation with the number of shared cars with respect to total population. However, according the full models with non-linear terms, a positive relationship only exists for Randstad municipalities or cities which are not highly urbanized, which means that the resulting relationship depends more or less of the model composition. Also the presence of younger people between the ages of 20 and 25 years has a significant impact on the presence of car sharing services in most of the models, but sometimes positive and sometimes negative. That's why it is not possible to draw general conclusions about the assumed positive relationship between the relevant age groups and the demand for car sharing services, because full evidence is lacking.

Finally, income is significant in some of the customer models, but is not significant at all in the full models, which means that there is no evidence for a general positive relationship between the level of income and the demand to car sharing services.

Spatial characteristics

The spatial characteristics have less explanatory impact on the demand for car sharing services. In the models with only spatial characteristics, local and national accessibility by public transport, proximity to large railway stations, population density and the modal split of cycling seems to have a positive relationship with the presence of car sharing services. So, it can be concluded that there is evidence for the complementary relation as assumed by KpVV (2009), Meijkamp (2000) and Nanninga & Eerdmans (2006), between the availability of public transport and the use of bikes from a supply side perspective, because indicators are significant in the models with only spatial characteristics. This supports from a supply side perspective the offering of car sharing services as part of a total sustainable package on locations which are good accessible by public transport and bike.

However in the full models that take all relevant factors into account, only population density has a clear positive impact on the availability of car sharing services. Local accessibility by public transport also affect the presence of car sharing services in a positive way, but not for highly urbanized and strong urban municipalities. National accessibility by public transport and the modal split of cycling only have explanatory power in a positive way if education has been excluded. So evidence for a general positive relationship between the availability of public transport and the use of cycling on the one hand and the demand for car sharing services on the other hand is lacking, also because regional accessibility by public transport and proximity to train stations do not have a significant positive impact in all of the models.

General application to the market

So it seems that the appropriate type of customer has a college or university degree, does not own a car, lives in a household without children and may be between the ages of 25 and 45 years. With respect to the living area, especially some level of density has been needed in order to order car sharing profitable. Other spatial indicators with respect to availability of public transport and the use of cycling may be relevant, but do not have much explanatory power at the end.

However, it is possible that there exists some overlap between spatial and customer indicators, because the appropriate type of customer that has no children, possess no car, has a college or university degree and is between the ages of 25 and 45 years probably prefer to live in a high density and urban environment (Florida, 2002; Jong & Duin, 2011; Storper & Manville, 2006). Although, the customer characteristics possess a higher explanatory power, spatial conditions may still be relevant, but remain latent in the full model.

If the appropriate types of customers live in high density areas, their revealed preference is to live in an urban environment (Storper & Manville, 2006). They do not own a car, but it could be that they have a latent preference for (sometimes) using a car, but it is not possible for a couple of reasons. The outcomes of the regressions give evidence to this theory and therefore offering car sharing services seems to have a chance of success in urban neighborhoods with this appropriate type of customer.

Conversely, it is also possible that an appropriate type of customer who lives in a lower density area has a latent preference for less driving. The availability of car sharing services offers a solution for these customers. However, evidence for this is a little less strong, because density seems to be an important condition, also to offer car sharing services in a profitable way.

Finally, future market prospects for providing car sharing services seem to be good. It seems that the potential customer market for car sharing is growing, because significant factors develop in a positive way. Household sizes are continuously decreasing, the number of higher educated people will rise and younger people seems to be less interested in possessing a private car (Jong & Duin, 2011; Kuhnimhof *et al.*, 2012; Verweij *et al.*, 2010). Also urban resurgence and the renewed trend towards urbanization at both a global and national scale level provide more density and support for the provision of car sharing services, because of concentration of (higher-educated) people (Florida, 2002; Glaeser & Gottlieb, 2006; Jong & Duin, 2011).

5.2. Assessment

Based on the discussion and analyses of the results, it is possible to decide about the hypotheses which will be done in this section.

Hypothesis 1: There is a positive relationship between the accessibility provided by public transport and the use of car sharing services

The spatial characteristics and restricted models provide evidence of a positive relationship between most indicators and the presence of car sharing services. However, in the most important full models, only local accessibility has some added explanatory power. Because of the lack of explanatory power of most public transport indicators in the full model and the fact that not all indicators of have a clear positive impact, there is not enough evidence for a general positive relationship, so the hypothesis will be rejected.

Hypothesis 2: There is a positive relationship between the share of cycling in the modal split and the use of car sharing services
According the restricted model, no positive and significant relationship exists between the modal split of cycling on short distances and the availability of car sharing services, but in some of the multiple models a significant relationship is present. However, in the most important full models, cycling remains insignificant. That's why full evidence of a general positive relationship is lacking and the hypothesis will be rejected.

Hypothesis 3: There is a positive relationship between density and the use of car sharing services
Population density as indicator of density is significant in the restricted, spatial and most important full models. That's why there is strong evidence that density has a general positive impact on the availability and the use of car sharing services, so this hypothesis will be accepted.

Hypothesis 4: There is a positive relationship between the presence of people between the ages of 25 and 44 years old and the use of car sharing services
The restricted model indicates an increasing positive impact of people between the ages of 25 and 45 years on the presence of car sharing services from a certain minimum presence of this age category. Also the customer characteristics models indicate a strong positive relationship, but in the full models, the presence of people between the ages of 25 and 45 years has only a positive impact for Randstad municipalities or municipalities which are not highly urbanized, so it depends on the model composition. Probably, there exists a positive relationship, but because full evidence of a general positive impact for all types of municipalities is lacking, this hypothesis will be rejected.

Hypothesis 5: There is a positive relationship between the level of education and the use of car sharing services
Although, data about the presence of higher-educated people were only available for municipalities with more than 30.000 inhabitants, the strong significance of this variable in all of the models gives a very clear indication of its general positive impact on the use of car sharing services, so the hypothesis will be accepted.

Hypothesis 6: There is a negative relationship between household size and the use of car sharing services
The average household size remains insignificant in all of the models with only linear terms. However, in all of the the square of the average household size is significant and has a declining negative relationship with the availability of car sharing services towards a minimum presence somewhere between an average household size of 2.2 and 2.5. Although, there exists no negative relationship anymore after a minimum size of up to 2.5 persons, there is strong evidence for a general declining negative relationship until this minimum size, so the hypothesis will be accepted.

Hypothesis 7: There is a negative relationship between car ownership and the use of car sharing services
In most of the customer characteristics models and the full models with non-linear terns, there exists a positive relation between the number of inhabitants per private car and the

presence of shared cars with respect to total population, which means a negative relationship between car ownership and the availability of car sharing services. The models provide some evidence that this relationship is somewhat stronger for little urban municipalities and less strong for Randstad municipalities. Because both customer characteristics and full models indicate the negative impact on the presence of shared cars, there is strong evidence for a general negative relationship, so the hypothesis will be accepted.

Hypothesis 8: There is a positive relationship between the level of income and the use of car sharing services

Although, the restricted and customer characteristics models provide some evidence of a positive significant relationship between average disposable income and the availability of car sharing services, this evidence has not been supported by a positive significant impact of the average disposable income in the full models. So, a clear general positive impact is lacking and therefore this hypothesis will be rejected.

6. Case study: Suitable areas for car sharing services in Rotterdam

In this chapter, the findings from the previous chapters will be applied to the local scale level. Based on these results, a ranking has been made in order to identify the highest potential residential neighborhoods for offering car sharing services in the municipality of Rotterdam. The choice for Rotterdam has been based on the scarce supply of car sharing services compared to other large cities in the Netherlands (KpVV, 2013).

In order to identify neighborhood potential, the scores of the areas on the indicators with the highest explanatory power have been obtained and based on the deviation from the average score for Rotterdam, the potential has been calculated. The most important indicators are population density, average household size, car ownership, the presence of people between 25 and 45 years and the presence of higher educated people. Data about the first four indicators on neighborhood level have been obtained from CBS StatLine (2013). The presence of people between the ages of 25 and 45 years have been measured in the same way as in the previous sections. Car ownership has been measured as the number of private cars per household and an indication of population density has been given by the dummies for urbanity which have also been used in previous chapter. Data about education come from the municipality of Rotterdam. Data about the real presence of higher-educated people per neighborhood are not available, only a categorical index score on a scale of one to five, which gives an indication about the educational level in the different neighborhoods in Rotterdam, is free available. A score of 5 means that a neighborhood has a strong educational level, while a score of one indicates a very weak level of education (Gemeente Rotterdam, 2012).

Table 5 presents the scores of the different boroughs and neighborhoods on the different indictors and based on these outcomes, the potential of offering car sharing services has been calculated. For the continuous indicators population , average household size and car ownership, standard deviations with respect to the average scores for Rotterdam have been computed. If neighborhood outcomes are within one standard deviation of the Rotterdam's average, they will be considered as medium potential, within two standard deviations as high or low potential and if they exceed two standard deviations, the neighborhood can be considered as very high potential or very low potential. Because urbanity is already on a scale of one to five, each degree of urbanity represents a level of potential with value one for highly urbanized as very high potential and value five for rural as very low potential. Educational level is also available on a scale of one to five, but because a value of three means already an insufficient and moderate score and in practice a score of one does not occur, a score of two has been assessed as very low potential and the maximum score of five as very high potential. In the table below, the standardized values and the colors which indicate the level of potential have been displayed.

Table 4: Colors and standardized values for the different levels of potential

very high potential	(5)
high potential	(4)
medium potential	(3)
low potential	(2)
very low potential	(1)

Source: Own processing

However, not every indicator has the same impact on the level of car sharing services. Based on measuring the difference between the values of the adjusted R-squared in the regressions of the full models in section 4.4 with and without the inclusion of the respective explanatory variables, the weights have been determined. The education classification has a very high weighting of 0.5, while urbanity and private cars per household account for a weight of 0.15 and the presence of population between the age of 25 and 45 years each have a weight of 0.1. In order to calculate total potential for offering car sharing services in the different neighborhoods, the weights are multiplied with the standardized value for potentiality for each indicator and have been accumulated for the different indicators.

Table 5: Scores and potential of offering car sharing services per neighborhood[13]

Total score	Population 25-45 years (%)[14]	Average household size[15]	Private cars per household[16]	Educational level	Urbanity
Netherlands	26	2,2	1	-	2
Rotterdam	31	1,9	0,7	4	1
Rotterdam Centrum	42	1,6	0,7	5	1
Stadsdriehoek	49	1,5	0,9	5	1
Oude Westen	31	1,8	0,4	3	1
Cool	40	1,5	0,5	5	1
C.S. kwartier	56	1,4	2	5	1
Nieuwe Werk	38	1,5	0,9	5	1
Dijkzigt	50	1,2	0,4	5	1
Delfshaven	35	1,9	0,5	4	1
Delfshaven	39	1,6	0,4	5	1
Bospolder	31	2,1	0,5	3	1
Tussendijken	32	1,9	0,4	3	1
Spangen	33	2,3	0,6	3	1
Nieuwe Westen	33	2	0,5	4	1
Middelland	37	1,8	0,4	4	1
Oud-Mathenesse	40	1,7	0,5	4	1
Witte Dorp	25	2,3	0,6	4	1
Schiemond	36	2	0,6	3	1
Overschie	28	2	0,9	4	2
Kleinpolder	28	1,9	0,8	4	2
Schieveen	26	2,5	1,5	4	5
Zestienhoven	25	2,6	1,5	4	4
Overschie	28	2,2	1	4	2
Landzicht	24	1,9	0,7	4	4
Noord	40	1,8	0,5	5	1
Agniesebuurt	36	1,7	0,5	4	1
Provenierswijk	39	1,7	0,4	4	1
Bergpolder	52	1,5	0,4	5	1
Blijdorp	45	1,7	0,6	5	1
Liskwartier	37	1,9	0,6	5	1
Oude Noorden	34	1,9	0,5	3	1
Hillegersberg-Schiebroek	27	2,1	0,9	5	2
Schiebroek	27	2	0,7	4	1
Hillegersberg-Zuid	36	2	0,9	5	1
Hillegersberg-Noord	23	2	0,9	4	2
Terbregge	28	2,7	1,2	5	4

[13] Potential has been computed based on the standard deviations. A value which is more (less) than two deviations of the average can be considered as very high (very low) potential, more (les) than one standard deviation as high (low) potential and within one standard deviation as medium potential. Standard deviations have been computed by using the next equation: $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$. Because one neighborhood has a larger population than another, each difference between neighborhood value and average has been multiplied by total population of the respective neighborhood. Data with respect to total neighborhood population have been included in appendix III.

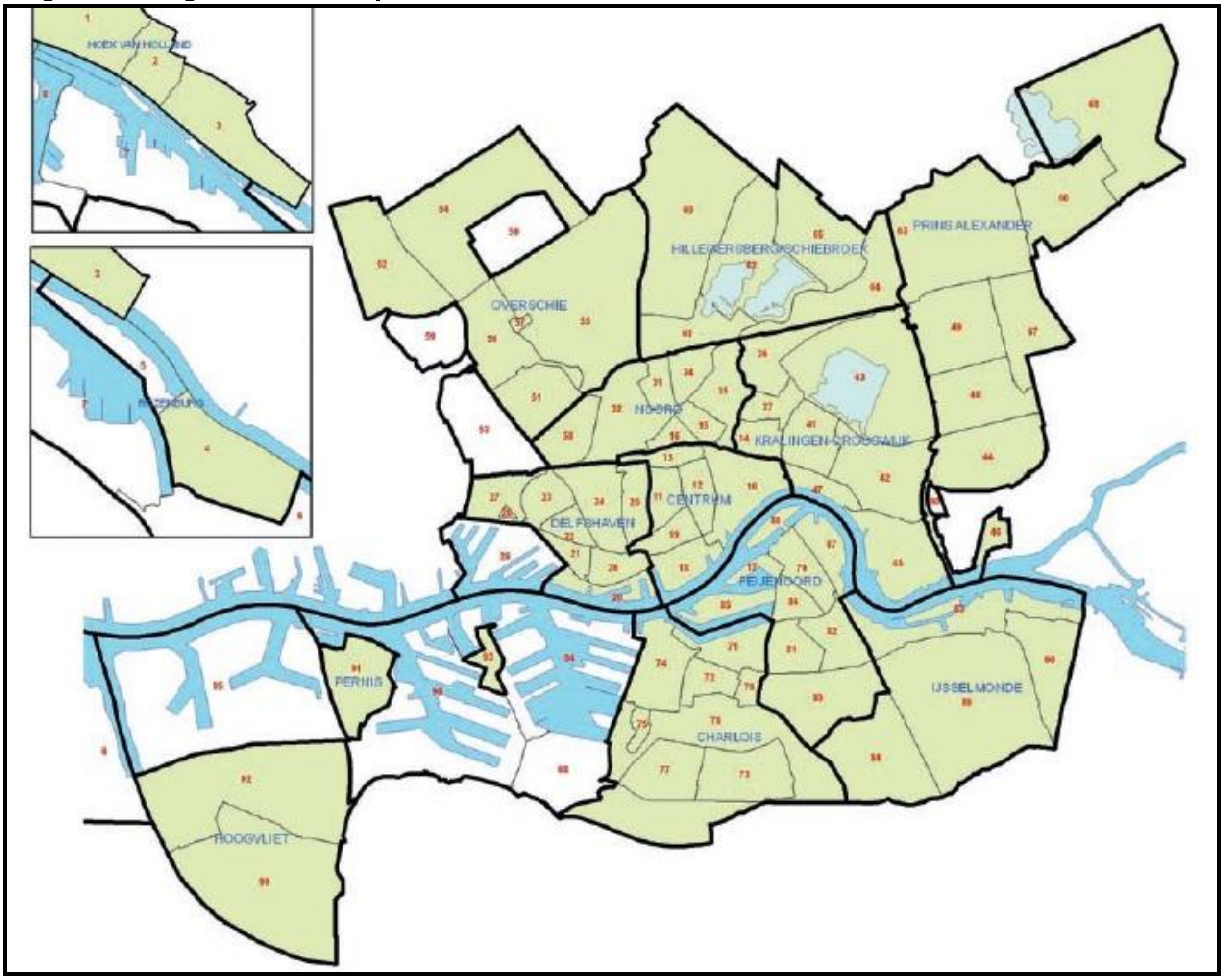
[14] $\sigma \approx 7.16$
[15] $\sigma \approx 0.26$
[16] $\sigma \approx 0.20$

Molenlaankwartier	21	2,3	1,1	5	2
Kralingen-Crooswijk	33	1,7	0,6	5	1
Rubroek	35	1,7	0,5	5	1
Nieuw-Crooswijk	36	1,7	0,8	4	1
Oud-Crooswijk	30	2	0,5	3	1
Kralingen-West	35	1,7	0,5	5	1
Kralingen-Oost	26	1,9	0,8	5	1
Kralingse Bos	26	2,2	1,1	5	2
De Esch	32	1,6	1	5	2
Struisenburg	40	1,4	0,6	5	1
Feijenoord	31	2	0,6	3	1
Kop van Zuid	55	1,4	0,6	5	1
Kop van Zuid-Entrepot	36	2	0,6	4	1
Vreewijk	22	1,9	0,6	3	1
Bloemhof	31	2,1	0,5	3	1
Hillesluis	33	2,2	0,6	3	1
Katendrecht	35	2,1	0,6	4	1
Afrikaanderwijk	28	2,2	0,5	2	1
Feijenoord	30	2,2	0,5	3	1
Noordereiland	35	1,7	0,6	5	1
IJsselmonde	27	2	0,7	3	1
Oud-IJsselmonde	32	2,1	1	5	2
Lombardijen	28	1,9	0,7	4	1
Groot-IJsselmonde	25	2	0,7	4	1
Beverwaard	27	2,3	0,8	3	2
Pernis	28	2,2	1	5	4
Prins Alexander	25	2,1	0,8	5	1
's-Gravenland	21	2,4	1	5	2
Kralingse Veer	29	2,4	1	5	3
Prinsenland	23	1,9	0,8	5	1
Het Lage Land	26	1,7	0,7	5	1
Ommoord	20	1,9	0,8	4	1
Zevenkamp	26	2,2	0,8	4	2
Oosterflank	27	1,9	0,7	4	1
Nesselande	38	2,7	1,1	5	3
Charlois	34	1,9	0,6	3	1
Tarwewijk	37	2	0,5	3	1
Carnisse	42	1,8	0,5	3	1
Zuidwijk	28	1,9	0,6	3	1
Oud-Charlois	34	1,9	0,6	3	1
Wielewaal	23	1,8	0,6	3	2
Zuidplein	38	1,5	0,6	4	1
Pendrecht	32	2	0,6	3	1
Zuiderpark	17	1,3	0,3	4	1
Heijplaat	24	2	0,8	4	5
Hoogvliet	24	2,2	0,9	4	2
Hoogvliet-Noord	28	2,2	0,9	3	2
Hoogvliet-Zuid	22	2,1	0,8	4	2
Hoek van Holland	23	2,2	1	5	3
Rozenburg	25	2,2	1	5	3

Source: CBS StatLine (2013), Gemeente Rotterdam (2012) and own processing

Based on the outcomes in table 5, it can be concluded that most neighborhoods in Rotterdam can be considered as medium potential for car sharing services which is quite logical because calculations have been made based on the deviation of the average scores for the municipality of Rotterdam. However, there are also a number of boroughs and neighborhoods which offer high potential for car sharing services. Especially, some neighborhoods in the boroughs of Rotterdam-Centrum, Noord, Hillegersberg-Schiebroek and Prins Alexander are high potential within Rotterdam. The map of Rotterdam in figure 8 shows that these boroughs and neighborhoods are especially concentrated in the more rich northern, eastern and city center areas of Rotterdam. The southern and western part of the city do not offer much potential for car sharing services, with the exception of the neighborhoods Delfshaven, Kop van Zuid, Noordereiland and Oud-IJsselmonde. The neighborhoods Schieveen, Zestienhoven, Wielewaal en Afrikaanderwjk have the lowest potential for offering car sharing service, because conditions with respect to population density, household size, age, education and car ownership are worse.

Figure 8: Neighborhood map Rotterdam



A Centrum
10 Stadsdriehoek
11 Oude Westen
12 Cool
13 C.S. Kwartier
18 Nieuwe Werk
19 Dijkzigt

C Delfshaven
20 Delfshaven
21 Bospolder
22 Tussendijken
23 Spangen
24 Nieuwe Westen
25 Middelland
27 Oud-Mathenesse
28 Witte Dorp
29 Schiemond

D Overschie
51 Kleinpolder
52 Noord Kethel
54 Schieveen
55 Zestienhoven
56 Overschie
57 Landzicht

E Noord
15 Agniesebuurt
16 Provenierswijk
31 Bergpolder
32 Blijdorp
34 Liskwartier
35 Oude Noorden
58 Blijdorpsepolder

F Hillegersberg-Schiebroek
60 Schiebroek
61 Hillegersberg-zuid
62 Hillegersberg-noord
64 Terbregge
65 Molenlaankwartier

H Kralingen-Crooswijk
14 Rubroek
36 Nieuw Crooswijk
37 Oud Crooswijk
41 Kralingen-west
42 Kralingen-oost
43 Kralingse Bos
45 De Esch
47 Struisenburg

J Prins Alexander
44 's-Gravenland
46 Kralingseveer
48 Prinsenland
49 Het Lage Land
63 Ommoord
66 Zevenkamp
67 Oosterflank
68 Nesselande

wijkgrens
deelgemeentegrens

Bron: Gemeente Rotterdam
Bewerking: Centrum voor Onderzoek en Statistiek

L Feijenoord
79 Kop van Zuid-Entrepot
17 Kop van Zuid
80 Vreewijk
81 Bloemhof
82 Hillesluis
85 Katendrecht
86 Afrikaanderwijk
87 Feijenoord
88 Noordereiland

N IJsselmonde
83 Oud IJsselmonde
84 Lombardijen
89 Groot IJsselmonde
90 Beverwaard

P Charlois
71 Tarwewijk
72 Carnisse
73 Zuidwijk
74 Oud-Charlois
75 Wielewaal
76 Zuidplein
77 Pendrecht
79 Zuiderpark
93 Heijplaat

R Pernis
91 Pernis

S Hoogvliet
92 Hoogvliet-noord
99 Hoogvliet-zuid

T Hoek van Holland
1 Strand en Duin
2 Dorp
3 Rijnpoort

27 Rozenburg
4 Rozenburg
5 Noordzeeweg en omgeving

X Haven- en industriegebieder
6 Botlek
7 Europoort
8 Maasvlakte
26 Nieuw Mathenesse

40 Rivium
50 Bedrijventerrein Schieveen
53 Spaanse Polder
59 Bedrijvenpark RNW
94 Waalhaven
95 Vondelingenplaat
96 Eemhaven
98 Waalhaven Zuid

Source: Gemeente Rotterdam (2012, p.42)

Table 5 shows that conditions with respect to car ownership, population density, average household size and presence of people between the ages of 25 and 45 years are more favorable in Rotterdam compared to the Netherlands in general. The presence of higher-educated people Rotterdam in total population is approximately the same for the city and the country. So it can be stated that high potential neighborhoods in Rotterdam are probably also high potential neighborhoods in the Netherlands (Compendium voor de Leefomgeving, 2013).

In total, 20 of the 74 residential areas in Rotterdam can be considered as high potential for offering car sharing services and approximately 132.000 of the 616.000 inhabitants of Rotterdam live in these high potential neighborhoods (see appendix III). In order to reduce the demand for parking space in the older central city areas and to stimulate a more sustainable mobility behavior, the municipality may facilitate car sharing services providers in their demand for reserved parking space in the high potential neighborhoods. Of course, providers of car sharing services have to pay a fee for the use of parking space, because they earn money with providing the services.

In Amsterdam and Utrecht, common campaigns and communication of the municipality and car sharing providers in order to raise awareness and use, also contributes to the relatively high use of car sharing services in these municipalities (KpVV, 2013). Also in the high potential neighborhoods in Rotterdam, starting common campaigns and raising awareness may be beneficial. This can be done by handing out leaflets or vouchers for the use of car sharing services.

According the product life cycle theory, potential customers in the high potential neighborhoods may act as early adopters of car sharing services. If many of the targeted customers start with car sharing, other types of people and neighborhoods may follow.

7. Conclusions

In this chapter, the main findings with respect to the use of car sharing services will be presented. Section 7.1 describes the main conclusions by answering the research question and sub-questions. In section 7.2, a number of recommendations have been presented. Finally, Section 7.3 discusses some limitations.

7.1. Conclusions

In order to answer the main question of which kind of residential areas are most suitable for offering car sharing services, first the four sub-questions will be treated.

The first sub question was about the advantages and disadvantages of the use of car sharing services and this question has been answered in the theoretical part. In some municipalities the offering of car sharing services has been stimulated, because it is expected that this offering may support a more sustainable behavior of people with respect to mobility and may possibly be a solution for some mobility problems. In order to adequately address advantages and disadvantages of offering car sharing services, customers have been divided in former car owners and adopters which do not possess a private car before. Especially, the adoption of car sharing services by the first group has many advantages with respect to sustainable mobility, such as a reduction in the demand for parking space, a decrease in the number of car mileages, more use of complementary sustainable modes such as public transport and cycling, because they often put away their private cars. Moreover, they probably will be more conscious about their mobility behavior after adoption and they use shared cars which are often cleaner than private cars. However, a disadvantage is that the current number of car sharers is too little for already being a solution for the reduction of traffic and negative environmental effects.

Also the adoption of car sharing services by the customer group which do not possess a car seems to have some advantages. They will also be more conscious about their mobility behavior and it may prevent the purchase of a private car. Moreover, it also seems to fulfill a social goal, because a new mobility solution has been offered to people without a car. Disadvantages of the use of car sharing services by this group are less use of public transport and bikes and an increase in the number of car mileages, because some trips which previously have been made by public transport or bike are now being implemented by (shared) car. However, because advantages with respect to sustainable mobility seems to be more numerous compared to the disadvantages it is worth to examine the explanatory factors for the use of car sharing services.

The second sub-question addresses the impact of spatial characteristics on the use of car sharing services. According theory, especially density and the availability of facilities with respect to public transport and cycling are important explanatory factors. Also according the tests indicators such as the modal split of cycling on short distances, average accessibility by public transport on a local scale level and on a national scale level and proximity to important train stations all have a positive impact on the use of car sharing services. However if more explanatory factors have been taken into account, only population density has some explanatory power.

The third sub-question is about the main explanatory factors for the use of car sharing services with respect to customer characteristics. The most important theoretical relations have been examined by testing hypotheses with several multiple regression models by using a sample size of 69 and 100 municipalities. Especially, the presence of higher educated people seems to be a very important explanatory factor in a positive way. Car ownership seems to affect the use of car sharing services in a negative way and average household size in a diminishing negative way until a minimum level has been reached at an average household size somewhere between 2.2 and 2.5 persons. Also the presence of people between the ages of 25 and 45 years seems to have, but maybe not in general for each type of municipality. Finally, the average disposable income seems to have a positive impact on the use of car sharing services, but does not have much explanatory power compared to other indicators. Furthermore, the explanatory power of the common customer characteristics is much higher compared to the explanatory power of spatial characteristics, but this is especially due to the inclusion of the presence of higher-educated people.

The last sub-question is about identifying the neighborhoods with the highest potential for offering car sharing services in the case of Rotterdam. By weighting, computing and accumulating standardized scores for the most important explanatory factors such as level of education, population density, car ownership, average household size and presence of people between the ages of 25 and 45 years, an identification of the highest potential neighborhoods has been made. It can be concluded that especially neighborhoods in the center, northern and eastern part of the city have favorable conditions for the offering of car sharing services.

After addressing each of the sub questions it is possible to answer the main research question about which kind of residential areas offer the highest potential for offering car sharing services. Urban neighborhoods with a high population density, a lot of higher-educated people, a low level of car ownership, many households without children and probably also with a high presence of people between the ages of 25 and 45 years are most favorable for offering car sharing services. This kind of residential areas are often located in larger cities and that's why offering of car sharing services seems to be a transport solution for urban customers, but has less commercial potential for customers in low density areas. Probably also the availability of public transport and bike connections is relevant which support the idea of car sharing as part of a sustainable mobility package, but these factors do not have a large explanatory power.

Finally, future market prospects for providing car sharing services seem to be good. It seems that the potential customer market for car sharing is growing, because factors such as household sizes and the presence of higher-educated people develop in a favorable way. Moreover, younger people less often possess a car and the renewed trend of urbanization encourages high-density living.

7.2. Recommendations

One important recommendation to providers of car sharing services is to focus on urban areas with a lot of higher-educated people, households without children and a low degree of car ownership. These neighborhoods offer the highest potential for offering car sharing services in a profitable way. Customers may act as early adopters of car sharing services and possibly, other people and neighborhoods may follow if many current potential customers start with using car sharing. Also an approach to target new markets based on customer profile has been preferred above targeting on area characteristics.

Because the use of car sharing services probably has some social benefits, such as a reduction in the demand for parking space and a more sustainable travel behavior of customers, there is an incentive for local governments to stimulate the use of car sharing services. They may facilitate car sharing providers in their demand for parking space in high potential neighborhoods. It is also to start common campaigns with car sharing providers or to provide clear information about the possibilities of car sharing services. By distributing leaflets or by handing out vouchers for the use of car sharing services, awareness may increase and potential customers receive an incentive to use car sharing services.

With respect to the data and methods, it is recommended to use a more extensive dataset with data about the different explanatory indicators on neighborhood scale level in order to increase the reliability of the outcomes and address explanatory factors more adequately. By also taking into account changes over time, there is also corrected for time-specific factors.

Finally, also new concepts of car sharing already emerge, such as peer to peer car sharing that makes it possible to share customer's private car with other people, and one way car sharing which makes it possible to drop your car at your destination. These new concepts have not been included in the data about the number of shared cars per 100.000 inhabitants, because these concepts were not yet available in the year 2011. Moreover, the offering of peer to peer car sharing is less demand driven, because offering your private car does not cost anything. However, it is also highly recommended to examine the factors which explain the demand for car sharing services and to get insight in the effects on traffic and environment of these types of car sharing services. Possibly, the effects are larger because of a higher accessibility of this system compared to traditional car sharing services.

7.3. Limitations

There are also a few limitations which have possibly affected the outcomes of this research. The most important limitation is the lack of data about the presence of higher-educated people for smaller municipalities. Possibly, education has a less strong impact if data for smaller municipalities had been included.

Another limitation is that the supply of shared cars has been used as dependent variable in order to give an indication about demand. Possibly, supply and demand do not always match adequately. However, because the supply of shared cars in residential areas is highly demand-driven, these deviations from each other are probably not very high.

There are also some regression method specific limitations. High multicollinearity which lead to imprecise estimates may always be a potential problem in regression models, but by not including explanatory variables which are highly correlated at the same time, an attempt has been made to avoid this phenomenon. Also the direction of the causality between the explanatory variable and the dependent variable is often not clear in regression models, but because the Ramsey Reset test gives almost no indication about misspecification, there is no evidence of reversed causality at all.

Another issue might be the composition of the model. For some indicators, their significance depend on the model composition. In order to avoid this problem, a lot of different models have been composed. And the relationships as stated in the hypotheses have only been accepted if evidence has been provided in a lot of models.

Furthermore, the possibility of having some omitted variables always exists, but probably these omitted variables do not possess many explanatory power, because of the high values for the adjusted R-squared.

Finally, effects and changes over time have not been incorporated, because cross-sectional sample has been used, so it could be that other factors have a statistically significant impact in another year.

References

- Banister, D. (2008) *The sustainable mobility paradigm*. Transport Policy, Vol.15, no.2, pp. 73-80.
- Bavel, J. van (2006) *Multicausaliteit en multicollineariteit bij meervoudige regressie*. Tijdschrift voor Sociologie.
- Bertolini, L. (2010) *Planning Mobility*. Keynote speech delivered at the international symposium ''Networks for Mobility''. September 30 – October 1, Stuttgart.
- Beuningen, J. van, H. Molnar-in 't Veld & I. Bouhuijs (2012) *Personenautobezit van huishoudens en personen*. Den Haag/Heerlen: Centraal Bureau voor de Statistiek.
- Bryman, A. (2008) *Social Science Research Methods*. Oxford: Oxford University.
- CBS (2012) *Tijd- en plaatsonafhankelijk werken in 2010. Op weg naar het nieuwe werken?* Den Haag/Heerlen: Centraal Bureau voor de Statistiek.
- CBS StatLine (2013) *'Figures and statistics'*. [Online] <http://StatLine.cbs.nl/statweb/> (accessed on May 12, 2013).
- Compendium voor de Leefomgeving (2013) *Hoogopgeleiden, 2011*. [Online] <http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl2100-Opleidingsniveau-beroepsbevolking.html?i=15-12> (accessed on May 31, 2013)
- DHV (2007) *Vervoerwaardestudie Lijn 12 traject Roosendaal – Antwerpen*.
- Eerdmans, D., H. Nanninga & L.L. Schipholt (2006) *De deelauto in de binnenstad van Amsterdam. Terug- en vooruitblik*. Inno-V: Amsterdam.
- European Commission (2007) *Green Paper "Towards a new culture for urban mobility"*. Brussels.
- European Commission (2009) "*Action Plan for Urban Mobility*". Brussels.
- Florida, R. (2002) *The Economic Geography of Talent*. Annals of the Association of American Geographers, Vol. 92, no.4, pp. 743-755.
- Greenwheels (2013) *'Information about Greenwheels'*. [Online] <https://www.greenwheels.com/nl/Home/Particulieren/over-ons> (accessed on June 11, 2013).
- Geurs, K. et al. (2009) *Bereikbaarheid: perspectieven, indicatoren en toepassingen*. In: Wee, B. van & J.A. Annema (eds.) *Verkeer en Vervoer in hoofdlijnen*. Bussum: Coutinho, pp. 167-185.
- Gemeente Amsterdam (2009) *Autodelen*. Dienst Onderzoek en Statistiek.
- Gemeente Houten (2012) *'Information about cycling in Houten'*. [Online] <https://www.houten.nl/over-gemeente-houten/verkeer-en-vervoer/fietsvoorzieningen/> (accessed on July 16, 2012).
- Gemeente Rotterdam (2012) *Rotterdam sociaal gemeten, 4e meting Sociale Index*.
- Handy, S. (2002) *Accessibility- vs. mobility-enhancing strategies for addressing automobile dependence in the U.S*. Davis: Department of Environmental Science and Policy.
- Jeekel, H. (2011) *De autoafhankelijke samenleving*. Delft: Uitgeverij Eburon.
- Jong, A. de & C. van Duin (2011) *Regionale bevolkings- en huishoudensprognose 2011-2040: sterke regionale contrasten*. Den Haag/Heerlen: Centraal Bureau voor de Statistiek, Den Haag/Bilthoven: Planbureau voor de Leefomgeving.
- KNIG (2013) *'Data about Dutch municipalities'*. [Online] <http://www.waarstaatjegemeente.nl/index.php?id=615> (accessed on January 14, 2013).

- KpVV (2009) *Kiezen voor autodelen*. Utrecht: Kennisplatform voor Verkeer en Vervoer.
- KpVV (2013) *'Dashboard duurzame en slimme mobiliteit'*. [Online] <http://kpvvdashboard-4.blogspot.nl/ > (accessed on June 25, 2013).
- Kuhnimhof, T., R. Buehler, M. Wirtz & D. Kalinowska (2012) *Travel trends among young adults in Germany: increasing multimodality and declining car use for men*. Journal of Transport Geography.
- May, A. & G. Marsden (2010) *Urban transport and mobility*. Background paper for the 2010 International Transport Forum, on 26-28 May in Leipzig, Germany.
- Meijkamp, R. (2000) *Changing consumer behavior through eco-efficient services. An empirical study on car sharing in the Netherlands*. Delft: Technische Universiteit.
- Meyer, M.D. & E.J. Miller (2001) *Urban Transportation Planning (second edition)*. New York: Mc Graw Hill.
- Ministerie van Verkeer en Waterstaat (2003) *Tien jaar stimulering van gedeeld autogebruik*. Geschiedenis en resultaten. Rijkswaterstaat: Rotterdam.
- Ministeries VWS & VROM (2004) *Nota Mobiliteit. Naar een betrouwbare en voorspelbare bereikbaarheid*. Den Haag: Ministerie van Verkeer en Waterstaat, Ministerie van Volkshuisvesting Ruimtelijke Ordening en Milieu.
- Momo Carsharing (2010) *The State of European Car-Sharing*.
- MuConsult (2006) *Openbaar vervoer op het platteland. Hoofdrapport*. Amersfoort.
- Nanninga, H. & D.A. Eerdmans (2006) *Groeikansen voor autodelen*.
- Nationale Bereikbaarheidskaart (2013) 'Data about public transport accessibility'. [Online] <http://www.bereikbaarheidskaart.nl/> (accessed on January 10, 2013).
- Schoemaker, T. (2002) *Samenhang in vervoer- en verkeersystemen*. Bussum: Uitgeverij Coutinho.
- SER (2001) *Arbeidsmobiliteit in de EU*. Den Haag: Sociaal-Economische Raad.
- Shaheen, S., D. Sperling & C. Wagner (1998) *Carsharing in Europe and North America: Past, Present and Future*. Transportation Quarterly, Vol. 52, no.3, pp. 33-52.
- Smart Agent (2011) *Utrechts Autodelen: perceptie en praktijk*. Amersfoort.
- Stock, J.H. & M.W. Watson (2007) *Introduction to Econometrics*. Second Edition, Pearson International Edition.
- Storper, M. & M. Manville (2006) *Behaviour, Preferences and Cities: Urban Theory and Urban Resurgence*. Urban Studies, Vol. 43, no. 8, pp. 1247-1274.
- TC Tubantia (2012) *'Grensland Express heft het moeilijk'*. [Online] <http://www.tubantia.nl/regio/noordoost-twente/grensland-express-heeft-het-moeilijk-1.1730199> (accessed on January 16, 2013).
- TNO (2012) *De Top 20 van Europese grootstedelijke regio's 1995-2011; Randstad Holland in internationaal perspectief*. Delft: Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek.
- Transportation Research Board (2005) *Car-Sharing: Where and how it succeeds*. Washington.
- Urry, J. (2004) *The 'System' of Automobility*. Theory Culture Society, 21(4/5), pp. 25-39.
- Verweij, A., C. Sanderse & F. Van der Lucht (2010) *Scholing en opleiding: Wat zijn de verwachtingen voor de toekomst?* In: Volksgezondheid Toekomst Verkenning, Nationaal Kompas Volksgezondheid. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu.

- WBSCD (2001) *Mobility 2001. World mobility at the end of the twentieth century and its sustainability*. Geneva: World Business Council for Sustainable Development.
- WCED (1987) *Our common future*. World Commission on Environment and Development, Oxford University Press, 1987.
- Wee, B. van (2012) *Ruimtelijk beleid om mobiliteitsredenen?* Rooilijn, Vol. 45, no.3, pp. 168-173.
- Wegener, M. & F. Fürst (1999) *Land-use transport interaction: State of the art*. Dortmund: IRPUD.

Appendices

Appendix I

I.I List of Randstad municipalities

Table a. Randstad municipality
Aalsmeer
Almere
Alphen aan den Rijn
Amersfoort
Amstelveen
Amsterdam
Bloemendaal
Bunnik
Bussum
Capelle aan den Ijssel
Castricum
De Bilt
De Ronde Venen
Den Haag
Diemen
Gorinchem
Gouda
Haarlem
Heemskerk
Heemstede
Hellevoetsluis
Hillegom
Hilversum
Houten
Huizen
IJsselstein
Katwijk
Landsmeer
Leiden
Leiderdorp
Leidschendam
Lelystad
Leusden
Naarden
Nieuwegein
Noordwijk
Oestgeest
Ouder-Amstel
Purmerend
Rijswijk
Rotterdam
Schiedam
Soest
Stichtse Vecht
Utrecht
Voorschoten
Weesp
Wijdemeren

Wormerland
Zaanstad
Zeist
Zoetermeer
Zoeterwoude
Zuidplas

Source: Own processing based on TNO (2012)

I.II Correlation table

Table b: Correlation matrix

	ln_shc~p	caturban	ln_pop~s	age2025	age2545	age2045	avhous~d
ln_shcarspop	1.0000						
	100						
caturban	-0.1851*	1.0000					
	0.0652						
	100	100					
ln_popdens	0.3232*	-0.8052*	1.0000				
	0.0010	0.0000					
	100	100	100				
age2025	0.2608*	-0.5143*	0.3840*	1.0000			
	0.0088	0.0000	0.0001				
	100	100	100	100			
age2545	0.2324*	-0.6466*	0.4945*	0.6272*	1.0000		
	0.0200	0.0000	0.0000	0.0000			
	100	100	100	100	100		
age2045	0.2667*	-0.6581*	0.4996*	0.8374*	0.9509*	1.0000	
	0.0073	0.0000	0.0000	0.0000	0.0000		
	100	100	100	100	100	100	
avhousehold	-0.3337*	0.6845*	-0.5357*	-0.6698*	-0.5319*	-0.6393*	1.0000
	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	
	100	100	100	100	100	100	100
ln_avincome	0.1686*	0.1778*	0.0208	-0.4926*	-0.6023*	-0.6184*	0.1343
	0.0936	0.0767	0.8372	0.0000	0.0000	0.0000	0.1828
	100	100	100	100	100	100	100
higheduc	0.7241*	-0.4079*	0.3335*	0.5482*	0.4493*	0.5530*	-0.6302*
	0.0000	0.0005	0.0051	0.0000	0.0001	0.0000	0.0000
	69	69	69	69	69	69	69
ln_avdistr~n	-0.1408	0.2782*	-0.2615*	-0.0743	-0.1365	-0.1254	0.2846*
	0.1622	0.0051	0.0086	0.4623	0.1756	0.2140	0.0041
	100	100	100	100	100	100	100
ln_avdistr~f	-0.2216*	0.4079*	-0.3124*	-0.2864*	-0.2695*	-0.3029*	0.4982*
	0.0267	0.0000	0.0016	0.0039	0.0067	0.0022	0.0000
	100	100	100	100	100	100	100
avaccpt15	0.2453*	-0.3080*	0.3015*	0.2415*	0.3360*	0.3317*	-0.2017*
	0.0139	0.0018	0.0023	0.0155	0.0006	0.0007	0.0442
	100	100	100	100	100	100	100
ln_avaccpt30	0.2287*	-0.5234*	0.5458*	0.1759*	0.2568*	0.2501*	-0.4125*
	0.0221	0.0000	0.0000	0.0801	0.0099	0.0121	0.0000
	100	100	100	100	100	100	100
avaccpt60	0.3947*	-0.4812*	0.6082*	0.0483	0.1532	0.1267	-0.2605*
	0.0000	0.0000	0.0000	0.6330	0.1280	0.2089	0.0088
	100	100	100	100	100	100	100
avaccpt90	0.4376*	-0.3126*	0.4754*	-0.0413	0.1120	0.0622	-0.0656
	0.0000	0.0015	0.0000	0.6835	0.2672	0.5385	0.5164
	100	100	100	100	100	100	100
avaccpt120	0.3861*	-0.2254*	0.3868*	-0.0811	0.1258	0.0561	0.0132
	0.0001	0.0242	0.0001	0.4225	0.2125	0.5796	0.8964
	100	100	100	100	100	100	100
drandstad	0.1270	-0.2365*	0.2958*	-0.1381	-0.0480	-0.0885	0.0424
	0.2080	0.0178	0.0028	0.1706	0.6355	0.3811	0.6752
	100	100	100	100	100	100	100
ln_cyclmod~t	0.0074	0.1791*	-0.1030	-0.0736	-0.2131*	-0.1788*	0.1909*
	0.9416	0.0746	0.3080	0.4666	0.0333	0.0751	0.0572
	100	100	100	100	100	100	100
ln_cyclsho~s	0.1278	0.1639	-0.1184	-0.0166	-0.0712	-0.0566	0.1587
	0.2052	0.1031	0.2407	0.8695	0.4814	0.5760	0.1149
	100	100	100	100	100	100	100
carownership	0.2648*	-0.3863*	0.3171*	0.4544*	0.3727*	0.4421*	-0.4909*
	0.0078	0.0001	0.0013	0.0000	0.0001	0.0000	0.0000
	100	100	100	100	100	100	100
durban1	0.3263*	-0.5934*	0.4393*	0.4139*	0.4701*	0.4943*	-0.5635*
	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	100	100	100	100	100	100	100
durban2	-0.0900	-0.4900*	0.4946*	0.2003*	0.2686*	0.2681*	-0.2386*
	0.3730	0.0000	0.0000	0.0457	0.0069	0.0070	0.0168
	100	100	100	100	100	100	100
durban3	-0.1243	0.3318*	-0.3822*	-0.2431*	-0.2406*	-0.2654*	0.3243*
	0.2177	0.0007	0.0001	0.0148	0.0159	0.0076	0.0010
	100	100	100	100	100	100	100
durban4	0.0384	0.6203*	-0.4683*	-0.2949*	-0.4380*	-0.4246*	0.3183*
	0.7045	0.0000	0.0000	0.0029	0.0000	0.0000	0.0012
	100	100	100	100	100	100	100
durban5	-0.0901	0.3732*	-0.2511*	-0.0691	-0.0866	-0.0883	0.2044*
	0.3728	0.0001	0.0117	0.4942	0.3914	0.3825	0.0413
	100	100	100	100	100	100	100

	ln_avi~e	higheduc	ln_avd~n	ln_avd~f	avacc~15	ln_av~30	avacc~60
ln_avincome	1.0000						
	100						
higheduc	0.2117*	1.0000					
	0.0807						
	69	69					
ln_avdistr~n	0.0535	-0.1223	1.0000				
	0.5967	0.3168					
	100	69	100				
ln_avdistr~f	-0.0229	-0.3789*	0.3757*	1.0000			
	0.8208	0.0013	0.0001				
	100	69	100	100			
avaccpt15	-0.0807	0.2771*	-0.1461	-0.0879	1.0000		
	0.4249	0.0211	0.1469	0.3845			
	100	69	100	100	100		
ln_avaccpt30	0.1635	0.2938*	-0.5563*	-0.3814*	0.2753*	1.0000	
	0.1040	0.0143	0.0000	0.0001	0.0056		
	100	69	100	100	100	100	
avaccpt60	0.4154*	0.3636*	-0.2187*	-0.3008*	0.2556*	0.7237*	1.0000
	0.0000	0.0021	0.0288	0.0024	0.0103	0.0000	
	100	69	100	100	100	100	100
avaccpt90	0.4553*	0.3879*	-0.0769	-0.0975	0.2269*	0.5544*	0.8961*
	0.0000	0.0010	0.4468	0.3347	0.0232	0.0000	0.0000
	100	69	100	100	100	100	100
avaccpt120	0.3918*	0.3577*	-0.0241	-0.0028	0.1507	0.3602*	0.7219*
	0.0001	0.0026	0.8122	0.9776	0.1346	0.0002	0.0000
	100	69	100	100	100	100	100
drandstad	0.4973*	0.0752	0.1281	-0.0103	0.0814	0.3374*	0.6369*
	0.0000	0.5389	0.2040	0.9186	0.4208	0.0006	0.0000
	100	69	100	100	100	100	100
ln_cyclmod~t	-0.0484	0.0373	-0.1466	0.0051	0.0674	-0.1703*	-0.2370*
	0.6322	0.7609	0.1455	0.9600	0.5054	0.0903	0.0176
	100	69	100	100	100	100	100
ln_cyclsho~s	-0.0668	0.1238	-0.1647	0.0250	0.1211	-0.1315	-0.1842*
	0.5093	0.3107	0.1016	0.8052	0.2301	0.1922	0.0666
	100	69	100	100	100	100	100
carownership	-0.2869*	0.2101*	-0.0579	-0.2402*	0.1207	0.1252	0.1048
	0.0038	0.0832	0.5670	0.0161	0.2318	0.2147	0.2995
	100	69	100	100	100	100	100
durban1	-0.1085	0.3849*	-0.1744*	-0.2533*	0.3844*	0.4539*	0.4416*
	0.2824	0.0011	0.0827	0.0110	0.0001	0.0000	0.0000
	100	69	100	100	100	100	100
durban2	-0.0714	-0.0102	-0.0150	-0.2188*	-0.0582	0.1608	0.1304
	0.4805	0.9336	0.8825	0.0287	0.5652	0.1100	0.1961
	100	69	100	100	100	100	100
durban3	-0.0166	-0.1769	-0.1349	0.1822*	-0.0644	-0.2369*	-0.2519*
	0.8694	0.1459	0.1808	0.0696	0.5245	0.0177	0.0115
	100	69	100	100	100	100	100
durban4	0.2611*	-0.2141*	0.3147*	0.2456*	-0.1395	-0.2658*	-0.1648
	0.0087	0.0773	0.0014	0.0138	0.1662	0.0075	0.1013
	100	69	100	100	100	100	100
durban5	-0.0997	.	0.1185	0.1033	-0.0927	-0.1146	-0.1801*
	0.3235	.	0.2405	0.3066	0.3591	0.2563	0.0729
	100	69	100	100	100	100	100

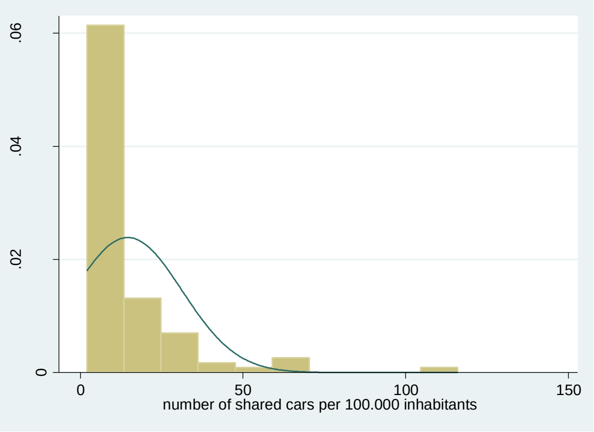
	avacc~90	avac~120	drands~d	ln_cyc~t	ln_cyc~s	carown~p	durban1
avaccpt90	1.0000						
	100						
avaccpt120	0.9049*	1.0000					
	0.0000						
	100	100					
drandstad	0.6469*	0.5162*	1.0000				
	0.0000	0.0000					
	100	100	100				
ln_cyclmod~t	-0.2653*	-0.3120*	-0.3850*	1.0000			
	0.0076	0.0016	0.0001				
	100	100	100	100			
ln_cyclsho~s	-0.1635	-0.1863*	-0.3568*	0.9182*	1.0000		
	0.1040	0.0635	0.0003	0.0000			
	100	100	100	100	100		
carownership	-0.0475	-0.0900	-0.0429	0.0776	0.0551	1.0000	
	0.6391	0.3733	0.6716	0.4428	0.5861		
	100	100	100	100	100	100	
durban1	0.2816*	0.1381	0.1829*	-0.1898*	-0.1727*	0.3512*	1.0000
	0.0045	0.1705	0.0686	0.0586	0.0858	0.0003	
	100	100	100	100	100	100	100
durban2	0.0662	0.0902	0.0892	-0.0590	-0.0620	0.0904	-0.2811*
	0.5129	0.3724	0.3774	0.5601	0.5399	0.3709	0.0046
	100	100	100	100	100	100	100
durban3	-0.1389	-0.0732	-0.1293	0.1956*	0.1859*	-0.1463	-0.2523*
	0.1680	0.4691	0.1999	0.0512	0.0641	0.1465	0.0113
	100	100	100	100	100	100	100
durban4	-0.0774	-0.0744	-0.0488	-0.0808	-0.0625	-0.2133*	-0.1418
	0.4441	0.4618	0.6299	0.4239	0.5366	0.0331	0.1592
	100	100	100	100	100	100	100
durban5	-0.1980*	-0.1906*	-0.1612	0.1682*	0.1281	-0.0764	-0.0502
	0.0483	0.0575	0.1092	0.0944	0.2041	0.4499	0.6197
	100	100	100	100	100	100	100

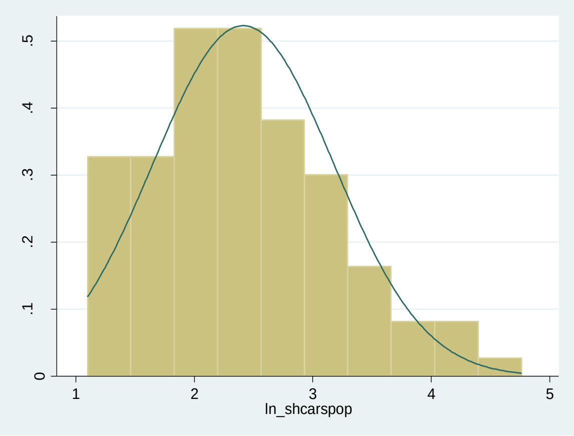
	durban2	durban3	durban4	durban5
durban2	1.0000			
	100			
durban3	-0.5739*	1.0000		
	0.0000			
	100	100		
durban4	-0.3226*	-0.2896*	1.0000	
	0.0011	0.0035		
	100	100	100	
durban5	-0.1142	-0.1025	-0.0576	1.0000
	0.2578	0.3100	0.5689	
	100	100	100	100

Source: own processing

I.III Logarithmic transformations

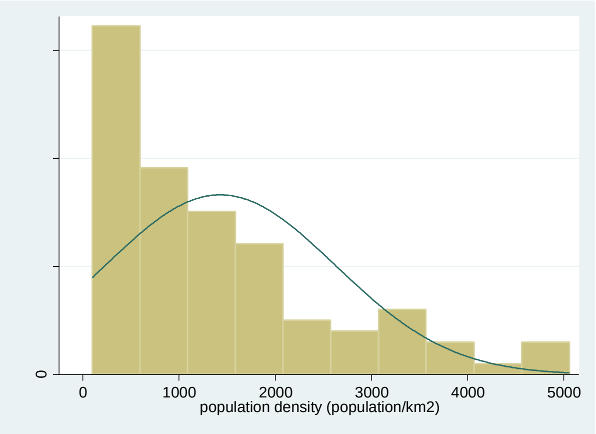
Figure a:presence car sharing (level) **(log)**

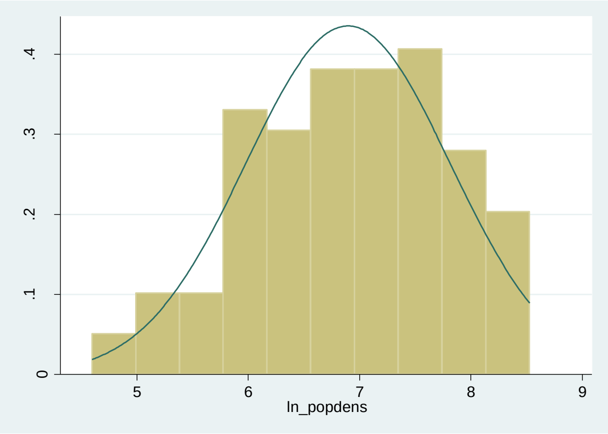




Source: Own processing

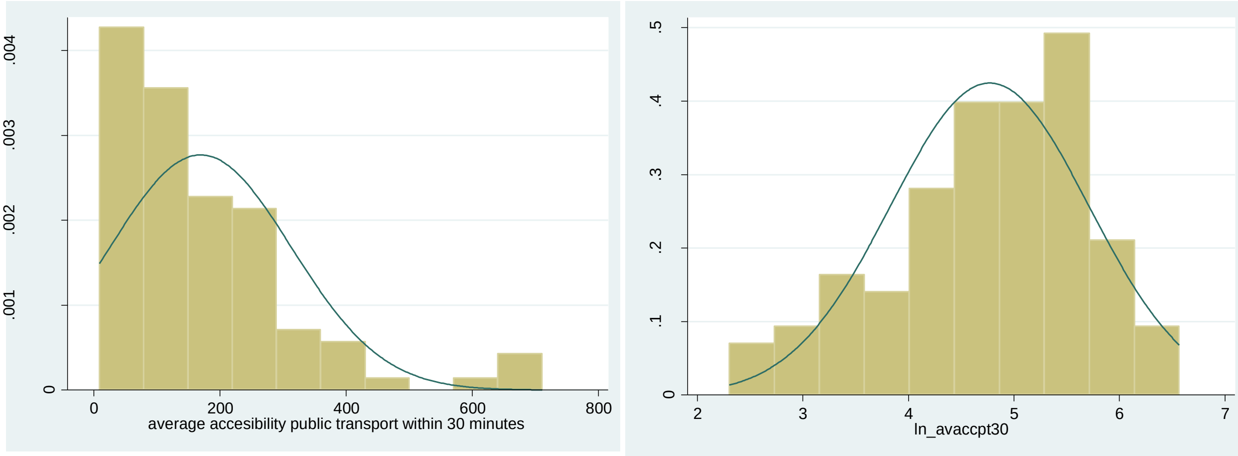
Figure b: population density (level) **(log)**





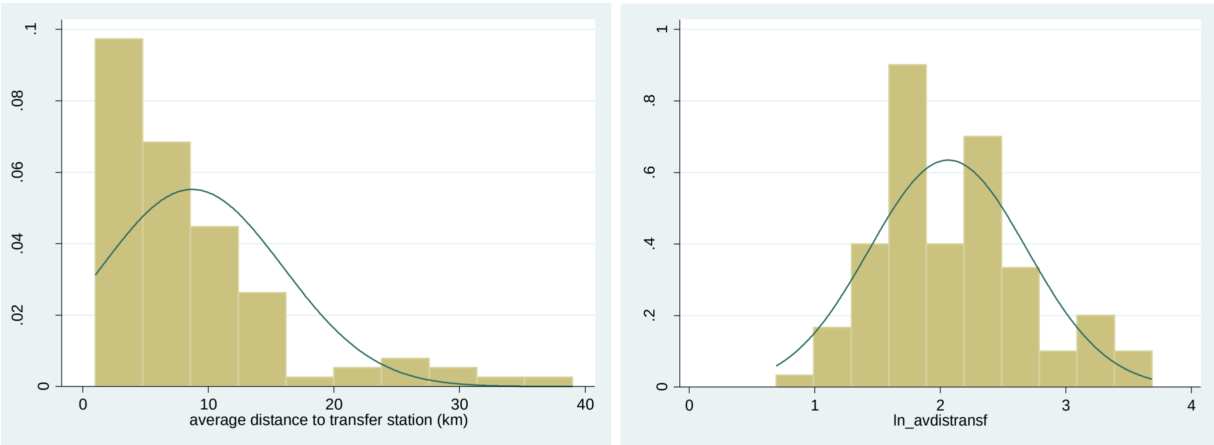
Source: Own processing

Figure c: regional accessibility (level) (log)



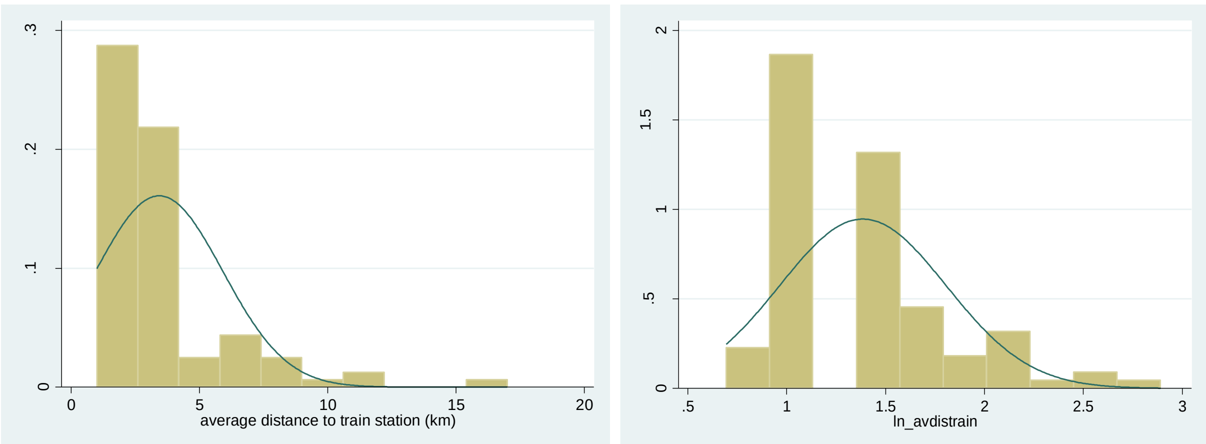
Source: Own processing

Figure d: proximity transfer (level) (log)



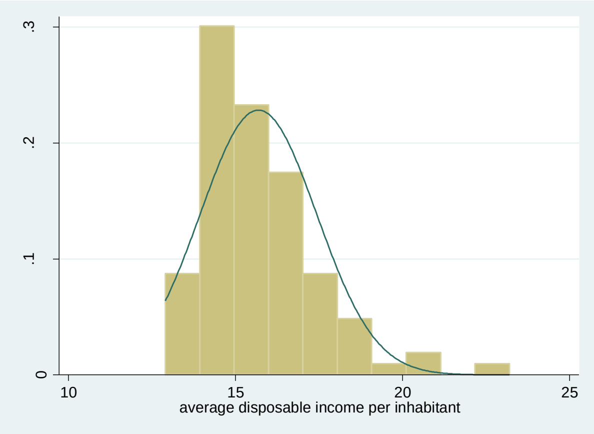
Source: Own processing

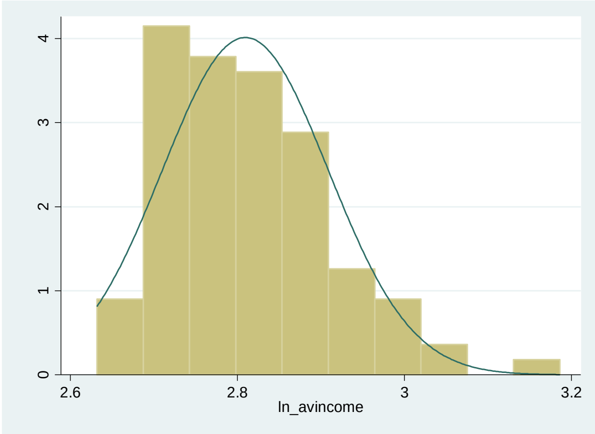
Figure e: proximity train (level) (log)



Source: Own processing

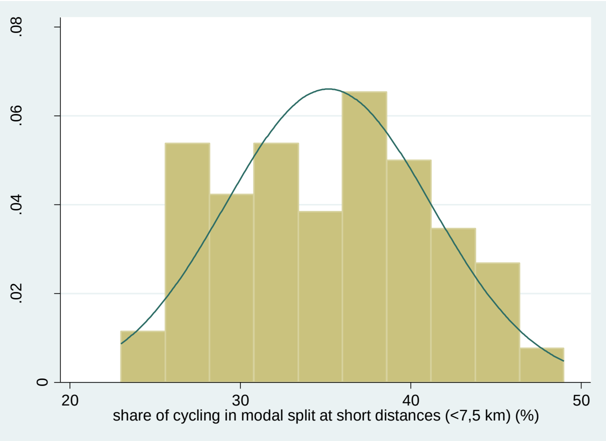
Figure f: income (level) **(log)**

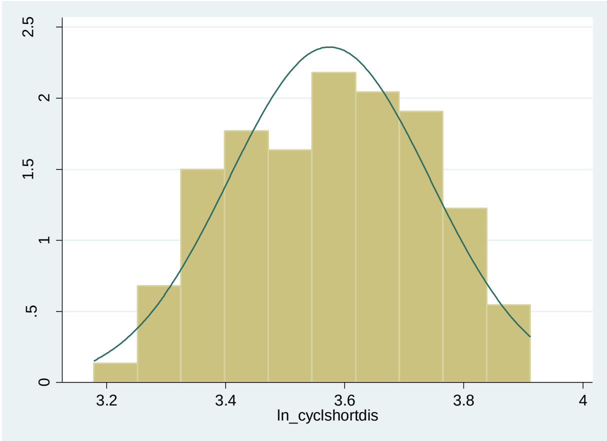




Source: Own processing

Figure g; cycling (level) **(log)**





Source: Own processing

Appendix II

II.I Restricted models

$\ln shcarspop = f(\ln avdistrain) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 95) =      2.10
                 Prob > F =      0.1054


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_avdistrain

         chi2(1)      =     0.07
         Prob > chi2  =   0.7894
```

$\ln shcarspop = f(\ln avdistransf) + \varepsilon$

```
 ( 1)  durban3 = 0
 ( 2)  urban3_transf = 0

       F(  2,    96) =    3.72
            Prob > F =    0.0277


Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 93) =      1.08
                 Prob > F =      0.3608


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_avdistransf durban3 urban3_transf

         chi2(3)      =     1.39
         Prob > chi2  =   0.7084



 ( 1)  drandstad = 0
 ( 2)  rstd_transf = 0

       F(  2,    96) =    4.10
            Prob > F =    0.0195


Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 93) =      0.67
                 Prob > F =      0.5750


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: drandstad ln_avdistransf rstd_transf

         chi2(3)      =     2.01
         Prob > chi2  =   0.5708
```

$\ln shcarspop = f(avaccpt15, avaccpt15^2) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 94) =      1.54
                 Prob > F =      0.2101


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: avaccpt15 avaccpt152

         chi2(2)      =     1.24
         Prob > chi2  =   0.5387
```

$\ln shcarspop = f(\ln avaccpt30\,, \ln avaccpt30^2) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 94) =      1.70
                 Prob > F =      0.1718


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_avaccpt30 ln_avaccpt302

         chi2(2)      =     3.94
         Prob > chi2  =   0.1394
```

$\ln shcarspop = f(avaccpt90) + \varepsilon$

```
 ( 1)  drandstad = 0
 ( 2)  rstd_pt90 = 0

       F(  2,    96) =    4.20
            Prob > F =    0.0178


Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 93) =      0.50
                 Prob > F =      0.6863


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: avaccpt90 drandstad rstd_pt90

         chi2(3)      =     4.87
         Prob > chi2  =   0.1819
```

$\ln shcarspop = f(avaccpt15, avaccpt15,^2\, avaccpt90, \ln avdistransf, rstd\_transf) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 91) =      0.66
                 Prob > F =      0.5786


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: avaccpt15 avaccpt152 avaccpt90 ln_avdistransf rstd_transf

         chi2(5)      =     2.06
         Prob > chi2  =   0.8411
```

$\ln shcarspop = f(\ln cyclshortdis) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 95) =      1.01
                 Prob > F =      0.3935


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_cyclshortdis

         chi2(1)      =     0.26
         Prob > chi2  =   0.6101
```

$\ln shcarspop = f(\ln popdens) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 95) =      0.60
                 Prob > F =      0.6186
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_popdens

         chi2(1)      =     1.22
         Prob > chi2  =   0.2684
```

$$\ln shcarspop = f(age2025) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 95) =      2.09
                  Prob > F =      0.1067


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age2025

         chi2(1)      =     1.14
         Prob > chi2  =   0.2860
```

$$\ln shcarspop = f(age2545, age2545^2) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 94) =      0.74
                  Prob > F =      0.5310


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age2545 age25452

         chi2(2)      =     0.50
         Prob > chi2  =   0.7786
```

$$\ln shcarspop = f(higheduc) + \varepsilon$$

```
 ( 1)  durban4 = 0
 ( 2)  urban4_educ = 0

       F(  2,    65) =    3.05
            Prob > F =    0.0543


Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 62) =      0.55
                  Prob > F =      0.6483


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: higheduc durban4 urban4_educ

         chi2(3)      =     4.20
         Prob > chi2  =   0.2403
```

$$\ln shcarspop = f(avhousehold, avhousehold^2) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 94) =      0.74
                  Prob > F =      0.5294


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: avhousehold household2

         chi2(2)      =     2.08
         Prob > chi2  =   0.3529
```

$$\ln shcarspop = f(carownership, carownership^2) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 94) =      0.44
                 Prob > F =      0.7281
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: carownership carownership2

         chi2(2)      =     0.96
         Prob > chi2  =   0.6191
```

$$\ln shcarspop = f(\ln avincome) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 95) =      0.44
                 Prob > F =      0.7217
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_avincome

         chi2(1)      =     1.37
         Prob > chi2  =   0.2422
```

II.II Spatial characteristics models

$$\ln shcarspop = f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, drandstad) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 93) =      1.64
                 Prob > F =      0.1865
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_cyclshortdis ln_avdistransf avaccpt90

         chi2(3)      =     3.14
         Prob > chi2  =   0.3701
```

$$\ln shcarspop = f(\ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, drandstad, rstd\_popdens, rstd\_transf, rstd\_pt90, urban2\_pt15, urban3\_transf) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 89) =      0.32
                 Prob > F =      0.8136
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_cyclshortdis avaccpt90 ln_avdistransf ln_popdens avaccpt15 urban2_pt15 urban3_transf

         chi2(7)      =     6.76
         Prob > chi2  =   0.4539
```

II.III Customer characteristics models

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, \ln avincome, carownership) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 62) =      1.38
                 Prob > F =      0.2567
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: higheduc age2545 ln_avincome

         chi2(3)      =     1.97
         Prob > chi2  =   0.5783
```

$$\ln shcarspop = f(age2025, age2545, avhousehold, \ln avincome\ , carownership) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 92) =      1.92
                 Prob > F =      0.1325
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age2025 age2545 ln_avincome carownership

         chi2(4)      =     0.76
         Prob > chi2  =   0.9432
```

$$\ln shcarspop = f(age2025, age2545, higheduc, avhousehold, household2, carownership, durban4, urban4\_car) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 57) =      0.33
                 Prob > F =      0.8039
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age2025 age2545 higheduc avhousehold household2 urban4_car carownership durban4

         chi2(8)      =     7.01
         Prob > chi2  =   0.5360
```

$$\ln shcarspop = f(age2545, avhousehold, household2, \ln avincome) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 92) =      0.50
                 Prob > F =      0.6838
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age2545 avhousehold household2 ln_avincome

         chi2(4)      =     1.96
         Prob > chi2  =   0.7436
```

II.IV Full models

$$\ln shcarspop = f(\ln avdistrain\ , \ln avdistransf\ , avaccpt15, \ln avaccp30\ , avaccpt90, \ln cyclshortdis, \ln popdens\ , age2025, age2545, higheduc, avhousehold, \ln avincome\ , carownership, drandstad) + \varepsilon$$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                 F(3, 60) =      0.80
                 Prob > F =      0.4971
```

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_popdens age2025 higheduc ln_avaccpt30 avaccpt15

         chi2(5)      =     5.89
         Prob > chi2  =   0.3171
```

$\ln shcarspop$
$= f(\ln avdistrain, \ln avdistransf, avaccpt15, \ln avaccp30, avaccpt90, \ln cyclshortdis, \ln popdens, age2025, age2545, avhousehold, \ln avincome, carownership, drandstad) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 89) =      2.33
                  Prob > F =      0.0797


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_shcarspop

         chi2(1)      =     2.28
         Prob > chi2  =   0.1312
```

$\ln shcarspop$
$= f(age2025, age2545, higheduc, avhousehold, household2, avaccpt15, \ln popdens, urban1\_pt15, urban2\_pt15, urban4\_car, rstd\_car, rstd\_popdens, rstd\_ag2545) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 51) =      0.59
                  Prob > F =      0.6244


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_popdens avaccpt15 age2025 age2545 avhousehold household2 higheduc carownership urban1_pt15 urban2_pt15
                    urban4_car rstd_car rstd_popdens rstd_age2545

         chi2(14)     =    10.37
         Prob > chi2  =   0.7346
```

$\ln shcarspop$
$= f(age2545, avhousehold, household2, avaccpt15, \text{avaccp90}, \text{carownership}, \ln popdens, \ln cyclshortdis, urban2\_pt15, urban4\_car, urban1\_ag2545) + \varepsilon$

```
Ramsey RESET test using powers of the fitted values of ln_shcarspop
       Ho:  model has no omitted variables
                  F(3, 85) =      1.41
                  Prob > F =      0.2444


Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: ln_popdens avaccpt15 age2545 avhousehold household2 urban1_age2545 carownership urban2_pt15 urban4_car
                    avaccpt90 ln_cyclshortdis

         chi2(11)     =    17.79
         Prob > chi2  =   0.0867
```

Appendix III

Table c: Total population per neighborhood in Rotterdam in 2012

Neighborhood	Population
Rotterdam	616260
Rotterdam Centrum	30410
Stadsdriehoek	13055
Oude Westen	9610
Cool	4190
C.S. kwartier	1090
Nieuwe Werk	1820
Dijkzigt	650
Delfshaven	74320
Delfshaven	6675
Bospolder	7330
Tussendijken	7105
Spangen	10195
Nieuwe Westen	18900
Middelland	11570
Oud-Mathenesse	7055
Witte Dorp	570
Schiemond	4920
Overschie	16045
Kleinpolder	7455
Schieveen	335
Zestienhoven	1090
Overschie	6720
Landzicht	380
Noord	50910
Agniesebuurt	4115
Provenierswijk	4630
Bergpolder	7830
Blijdorp	9705
Liskwartier	7535
Oude Noorden	16985
Hillegersberg-Schiebroek	42870
Schiebroek	15940
Hillegersberg-Zuid	7775
Hillegersberg-Noord	7970
Terbregge	3435
Molenlaankwartier	7755
Kralingen-Crooswijk	50505
Rubroek	8100
Nieuw-Crooswijk	2245
Oud-Crooswijk	8095
Kralingen-West	15575
Kralingen-Oost	7225
Kralingse Bos	125
De Esch	4425
Struisenburg	4710
Feijenoord	72480
Kop van Zuid	1820
Kop van Zuid-Entrepot	7755

Vreewijk	13710
Bloemhof	13945
Hillesluis	11460
Katendrecht	4445
Afrikaanderwijk	8770
Feijenoord	7285
Noordereiland	3295
IJsselmonde	58865
Oud-IJsselmonde	5955
Lombardijen	13405
Groot-IJsselmonde	27495
Beverwaard	12005
Pernis	4815
Prins Alexander	93985
's-Gravenland	8435
Kralingse Veer	1695
Prinsenland	10015
Het Lage Land	10370
Ommoord	24785
Zevenkamp	16460
Oosterflank	10635
Nesselande	11580
Charlois	64320
Tarwewijk	12210
Carnisse	10860
Zuidwijk	12145
Oud-Charlois	12995
Wielewaal	920
Zuidplein	925
Pendrecht	11320
Zuiderpark	1060
Heijplaat	1450
Hoogvliet	34065
Hoogvliet-Noord	12575
Hoogvliet-Zuid	21490
Hoek van Holland	9940
Rozenburg	12520

Source: CBS StatLine (2013)