Car: Book or buy?

An explorative study towards the modelling of carsharing participation in the Dutch travel demand model (LMS)

Ank van Paassen | Master's Thesis

TU Delft

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CAR: BOOK OR BUY?

An explorative study towards the modelling of carsharing participation in the Dutch travel demand model (LMS)

BY

ANK VAN PAASSEN

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THESIS COMMITTEE

Prof. dr. ir. C.G. (Caspar) Chorus	TU Delft
Dr. ir. S. (Sander) van Cranenburgh	TU Delft
Dr. ir. R. (Rob) van Nes	TU Delft
Dr. F. (Frank) Hofman	RWS VWMA
Dr. N. B. (Noortje) Groot	ILT (Formerly RWS VWMA)
Dr. J. (Jasper) Willigers	Significance

Candidate:

A. van Paassen
ID 4107144
E ankvanpaassen@hotmail.com
T 0619610940

Educational Institution:

Delft University of Technology
Faculty of Civil Engineering and Geosciences
MSc Transport, Infrastructure and Logistics
Track: Engineering

In collaboration with:

Rijkswaterstaat
Division: Water, Transport & Environment
Department: Models and Applications

&

Significance

An electronic version of this thesis is available at https://repository.tudelft.nl/

PREFACE

In front of you is the work that signifies the end of my time as a student and the start of a new chapter, where I will experience to what extent my education has prepared me for my working life. During my Masters Transport, Infrastructure & Logistics at the TU Delft, I have repetitively asked myself whether I should not just quit and start working already, until I stumbled across the topic travel demand modelling. From that moment on, I did not only knew what electives to take in the remaining part of my Masters, but also that I might have found a topic that could actually make me enjoy my graduation work. And so I did. Looking back on the past 8 months, I can definitely state that I am happy to have persisted. It was a time in which I have visited numerous inspiring events, met many interesting people, and learned more than I had ever expected.

I would not have had such a great experience without the support of numerous people.

First of all, special thanks go to my committee, an excessive list of supervisors. Prof. Caspar Chorus, the chair of the committee, for his approachable attitude and sharp questions that encouraged me to rethink my research without being demotivated. Rob van Nes and Sander van Cranenburgh, my supervisors at the TU Delft, who I have experienced to be very devoted with both my research and my well-being. Frank Hofman, my supervisor at Rijkswaterstaat, whose door was always open and who always took time for my questions. Noortje Groot, for the critical and extensive feedback on my written work, even after having switched to another employer. And last but not least, Jasper Willigers, my supervisor at Significance, for helping me out with all the errors that showed up in my estimation output and by sharing his broad knowledge on choice modelling.

I would also like to express my gratitude to everyone else who has contributed to the content of my thesis. Aron Vaas, Paul van Merriënboer and Huub Dubbelman for sharing their experiences in the carsharing market during the interviews. Lucas Harms and Peter Jorritsma, from the KiM, for providing their data on carsharing and digging into their memories to answer most of my questions. Matthijs de Gier, from Kantar Public (formerly known as TNS NIPO), for collecting the data for the KiM and clarifying any questions I still had left. Friso Metz, for sharing the data on the number of shared cars per municipality. Moreover, thanks go to my colleagues at Significance and Rijkswaterstaat, who were found to be very approachable and helpful with providing any additional information.

Last, I would like to thank my family and friends, for providing relaxation and diverting my attention from my graduation work. Special thanks go to Loran Tordoir, and not because I know this is the only part of this thesis he will ever read. He has been a great support, from the first day I set foot on the TU Delft campus, until now, waiting for me with a chilled bottle of champagne. Cheers!

A. (Ank) van Paassen
Delft, April 23, 2018

EXECUTIVE SUMMARY

Carsharing is a growing phenomenon that has gained increased attention of both local and national policy makers, because it is believed to reduce congestion, car travel demand, parking pressure and emissions. Moreover, carsharing is one of the main ingredients of another hot topic: Mobility-as-a-Service (MaaS). The Ministry of Infrastructure & Environment (I&E) has already conducted several pilots to better understand how the MaaS concept could be succesfully implemented.

Yet, much is unknown on how carsharing will impact the public environment towards the future. The believed positive effects of carsharing are currently based on case studies were carsharing participants are asked for their changed mobility behaviour. Such studies however do not take into account how fellow citizens respond to their carsharing neighbours and how this affects the total car ownership and car usage in the area. Moreover, knowledge is lacking on the the number of carsharing participants in the future. In current studies, future expectations are often based on an extrapolation of the experienced growth over the last few years, but this does not account for saturation in the carsharing market. Other studies base their conclusions on surveys in which people are asked for their potential carsharing participation under hypothetical circumstances, but here a hypothetical bias comes in. For urban planning practice, it is essential to gain a better understanding on carsharing saturation rates and the impact of carsharing on the future public environment in terms of car ownership and travel demand. Hence, the need has arised to incorporate carsharing in strategic travel demand models.

The aim of this study is therefore to explore how carsharing can be incorporated into strategic travel demand models, where the Dutch national transport model (LMS) is used as a case study. Carsharing is here defined as the repeated and consecutive joint use of motor vehicles by agreement between natural persons and a provider or between natural persons themselves originated from more than one household (Vereniging van Nederlandse Gemeenten, 2008). In order to use a shared car, a person has an agreement with a carsharing organization, in the form of a (paid) carsharing membership. Earlier studies towards carsharing have shown that only a limited part of the population is willing to participate in carsharing and the shared car is thus only accessible for a limited group op people. Therefore, in this thesis carsharing modelling is split in two parts: (1) modelling carsharing participation and (2) modelling the effect of carsharing participation on the total travel demand. The latter part is left for future research and this thesis thus focusses on the modelling of carsharing participation. Literature has suggested that causal interrelations exist among carsharing participation and car ownership and therefore this thesis approaches carsharing participation modelling jointly with car ownership modelling.

Hence, the research objective is formulated as follows:

1. Understand what factors affect carsharing participation by estimating choice models;
2. Specify how a joint model for carsharing participation and car ownership could be incorporated in the Dutch national transport model (LMS).

This research thus encloses a design task and hence the final product is a design of an empirical choice model. The empirical model for the LMS is designed in three steps, see also Figure 1. First, a conceptual model is designed that is based on knowledge gained from literature and interviews with representatives of carsharing organizations. Next, the conceptual model is operationalized into an empirical model with the help of revealed preference data obtained from the carsharing monitor of TNS NIPO, which was commissioned by the KiM in 2014. This empirical model, referred to as the 'best possible model', shows how a joint model for car ownership and carsharing participation should ideally

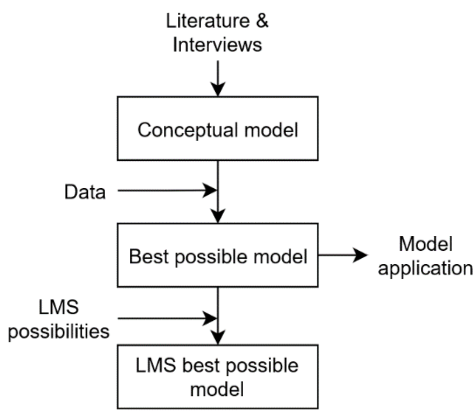

FIGURE 1: DESIGN PROCESS

be formulated, given the data available. The best possible model is applied on various scenarios, to determine the impact of (potential) future developments on carsharing participation. Then, the position of a carsharing participation and car ownership model in the LMS is assessed, needed adaptions to the LMS and the best possible model are discussed and a second empirical model is constructed: the 'LMS best possible model'.

In the first part of this thesis, where literature is consulted and interviews are conducted, this thesis is focussed on business-to-consumer- (B2C) and peer-to-peer (P2P) carsharing. B2C carsharing can be split in two types: one-way carsharing and round-trip carsharing. From the conceptual model onwards, the study is targeted on the modelling of round-trip carsharing only.

Results

Literature study has shown that one-way-, round-trip-, and P2P carsharing differ from each other in terms of operating area, parking possibilities, minimum rental periods, car access systems, costs structures and fleet variety. As a result of the differences, trip characteristics differ. One-way carsharing is mainly used for short distances as an alternative for public transport, P2P carsharing is used for trips often longer than a day and round-trip carsharing steers the middle course.

Interviews and literature showed numerous factors that explain carsharing participation. According to the interviews, the choice to participate in carsharing rather than to purchase a car is primarily motivated by costs and ease (carefree), and strengthened by environmental concern or parking regulations. A cost comparison between car ownership and carsharing participation showed that carsharing is financially interesting up to a yearly mileage of circa 4000 km. According to literature, household density, population size, a single household composition, high education, good public transport accessibility, public transport usage and commuters by foot all relate positively to carsharing participation. Moreover, carsharing awareness, carsharing participants among family and friends, a low shared car access time, and a high availability of the shared car further increase the chances to participate in carsharing. A negative impact was found for people who attach high psychological value to car ownership, people aged 65+ or in the possession of a car, commuters by car, and households with a high car travel demand. Furthermore, a large distance to facilities, good car accessibility from other zones, and high carsharing costs further lower the chances to participate in carsharing. Literature and interviews were found to be ambiguous on the effect of income, employment, gender and family composition (households with children) on carsharing participation. Among the different carsharing types, slight variations were found. The studies implied that B2C carsharing participants are higher educated, earn higher incomes, live in larger cities and closer to facilities, and are more often living in single households compared to P2P carsharing participants. Furthermore, the studies suggested that one-way users are more often men and in the possession of a car than round-trip carsharing participants are.

Literature study also showed various factors that explain car ownership: rural areas (+), distance to facilities (+), household size (+), household income (+), employment rate (+), driving licence possession (+), single household composition (-), and the share of female household members (-). When the head of the household is older (up to 80 years) or higher educated chances of car ownership are found to increase. Moreover, car ownership increases when the household's travel demand is higher and the distance to work is longer. High parking tariffs, public transport usage and high car ownership costs lower the car ownership rates.

With the knowledge gained from literature and interviews, a conceptual model is set up that is focused on round-trip carsharing in specific. The household is found to be the appropriate decision unit, because both car ownership and round-trip carsharing participation impact the household budget, the car availability, and transportation possibilities of all household members. For a visual representation of the conceptual model, it is referred to Figure 12 on page 39 of this report.

The operationalization of the conceptual model into an empirical model with the help of available data resulted in the 'best possible model'. This model is specified as a multinomial logit model on a household level that distinguishes five alternatives: 0n (no car, no round-trip carsharing), 1n (1 car, no round-trip carsharing), 2+n (2+ cars, no round-trip carsharing), 0rt (no car, round-trip carsharing), and 1+rt (1+ cars, round-trip carsharing). The 0n alternative functions as the reference alternative. For the estimation, the choice-set is limited to three alternatives in case the respondent was not aware with carsharing: 0n, 1n, and 2+n. Variables that are accounted for in the model, include the following: Number of adults, number of children, age category, household income, education, presence of carsharing participants in the social environment, and urbanization degree of the municipality the household is living in.

New insights that are gained from the estimation results of the best possible model include differences between carsharing participants that own a car and that do not. Households that do not own a car, but are participating in carsharing, are found to live in more urbanized regions, are less often elderly (>65), and are not found to be impacted by education levels. In contrast, households who combine car ownership with carsharing participation less often live in highly urbanized areas, are not found to be overly represented in a specific age category, and are more often highly educated. Moreover, empirical analysis showed that the car accessibility of a municipality and the presence of carsharing information on the municipality's website do not contribute to, nor oppose, carsharing participation.

Application of the best possible model on various scenarios showed that urbanization, increased carsharing awareness, and an increased financial prosperity will only have a marginal effect on the total round-trip carsharing participation. Increased carsharing participation in the social environment is however found to have the potential to significantly change the carsharing participation in the population. When everybody in the population is aware of carsharing and knows someone in their social environment that participates in carsharing, round-trip carsharing participation is expected to increase from 1.2% to 5.4% of the population.

Next it is explored how to incorporate the car ownership and carsharing participation model in the LMS environment. It is found that such a model could replace the current initial car ownership model, which is feed into the CARMOD program that is part of the LMS. The LMS is a forecast model that makes separate runs for both the base year and the future year. CARMOD is a program that adapts the ASC's of the initial car ownership (and carsharing participation) model for both the base year and the future year based on zonal- and national targets. The replacement of the initial car ownership model into a car ownership and carsharing participation model requires some adaptions to CARMOD inputs. First, zonal targets for carsharing participation in the base year are desirable, because zonal differences in carsharing participation are expected that are not caught in the model. Next, for the future year it is required that the national car ownership totals as determined by DYNAMO are corrected for carsharing participation, since carsharing participation affects the car ownership and vice versa. Last, ideally one would also have national targets for the total carsharing participation.

In the model specification of the LMS best possible model, few adaptions are made to the earlier estimated best possible model. The variable for the presence of carsharing participants in the social environment is excluded and moreover for the model estimation everyone is faced the full set of alternatives, since the carsharing awareness is not known in the synthetic population of the LMS model. The adaptions have resulted in a significant drop of the model fit compared to the earlier best possible mode. Apart from the fact this will result in less accurate results in model applications, it is also expected that the model is less accurate for future year applications, because: (1) the two excluded variables are expected to change (considerably) towards the future and (2) changes in the presence of carsharing participants in the social environment were found to have a relatively large effect on the carsharing participation in the scenario studies.

Limitations

A comparison of the LMS best possible model with the conceptual model, showed that a large number of potentially explaining variables are missing in the final model, which is primarily because those variables were not measured in the available data. A major shortcoming of the LMS best possible model is the fact that costs are not taken into account (for which an anticipated car travel demand is needed). Other shortcomings include the absence of land-use characteristics and alternative specific attributes, such as the access time to the private/shared car and the availability of the shared car.

Moreover, it should be noted that the quality of the sample data is debated for estimation purposes. The number of observations was low, the spatial representativeness questioned, and the choice-based nature limited the possibilities to test other modelling approaches. Hence, this thesis should mainly be considered as a first explorative attempt, but further studies are needed to affirm the findings.

Recommendations

First of all, it is recommended to reconsider the need to incorporate carsharing in the LMS model, given the fact that this study showed a limited number of carsharing participants in the future and a rather low shared car travel demand per carsharing participant. Hence, further studies to the actual market potential of carsharing are needed. Moreover, it can be considered to conduct scenario studies to the impact of various carsharing participation rates on the total travel demand.

In order to improve the model specification of the LMS best possible model, such that it more closely represents the conceptual model, it is recommended to collect new data. The data should include a larger set of variables, contain more observations and is preferably not choice-based. Because a sufficiently large sample is needed, it is recommended to combine the collection of the new estimation data with the national yearly travel survey (ODiN in The Netherlands). With the help of new data, it is advised to conduct empirical analysis to not only determine what other variables could be included in the utility functions, but also to explore other modelling approaches that can account for correlations between the carsharing- and car ownership alternatives.

Next, further studies are needed to the implementation of the carsharing model into the LMS. Adaptions to CARMOD have to be worked out in detail and studies are needed to the impact of carsharing participation on later steps of the LMS model, in which the SES program is of special interest. Here, mode choice, trip frequency and trip destination are jointly modelled.

Last, it is recommended to conduct further studies to one-way carsharing participation, since growth in this type is expected.

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List of abbreviations

AGV	Automated Guided Vehicles
ASC	Alternative Specific Constant
B2C	Business-to-consumer
BBI	BereikBaarheidsIndicator [Accessibility Indicator]
CBS	Centraal Bureau voor de Statistiek [Central Bureau for Statistics]
CS	Carsharing
CO	Car Ownership
KiM	Kennisinstituut voor Mobiliteitsbeleid [Knowledge Institute for Transport Policy Analysis]
LMS	Landelijk Model Systeem [National Model System]
MON	Mobiliteits Onderzoek Nederland [Mobility Survey Netherlands]
MPN	Mobiliteits Panel Nederland [Mobility Panel The Netherlands]
OD	Origin-Destination
ODiN	Onderzoek Onderweg in Nederland [Survey On the go in The Netherlands]
OViN	Onderzoek Verplaatsingen in Nederland [Survey Movements in The Netherland]
P2P	Peer-to-peer
RP	Revealed Preference
SP	Stated Preference

Glossary

0n	Model alternative: Household that owns **0** cars and does **not** participate in carsharing
1n	Model alternative: Household that owns **1** car and does **not** participate in carsharing
2+n	Model alternative: Household that owns **2 or more** cars and does **not** participate in carsharing
0rt	Model alternative: Household that owns **0** cars and does participate in carsharing
1+rt	Model alternative: Household that owns **1 or more** cars and does participate in carsharing
Breadwinner	The person in the household that contributes most to the household income. If individual incomes are equal, the oldest of the two is considered the breadwinner.
Estimation sample	The sample that is used for the mode estimation
One-way carsharing	Form of B2C carsharing whereby the car can be left at any (publicly accessible) location within the working area of the organization.
P2P carsharing	Form of carsharing whereby the car is rented from an individual, but via a third party.
Population sample	Refers to the yearly national travel survey that is conducted by CBS. In the period of 2003-2009, this survey was called the MON; in 2010-2017 the OViN was conducted. From 2018 onwards, the ODiN will be used.
Round-trip carsharing	Form of B2C carsharing whereby the car has to be brought back to the pick-up point.
Urbanization degree	Measure for the average household density of the municipality: 1. Urbanization degree 1: very densely urbanized (>2,500 hh/km²) 2. Urbanization degree 2: Densely urbanized (1,500 - 2,500 hh/km²) 3. Urbanization degree 3: Moderately urbanized (1,000 - 1,500 hh/km²) 4. Urbanization degree 4: Thinly populated areas (500 - 1,000 hh/km²) 5. Urbanization degree 5: Rural areas (<500 hh/km²)

CHAPTER 1

1 INTRODUCTION

Policy makers seem to have a new showpiece. It is called ‘carsharing’ and believed to reduce congestion, car travel demand, parking pressure and emissions. In times of rapid urbanization, increased environmental awareness, and traffic jams that break record after record, it is not surprising that carsharing is increasingly mentioned in policies on both national and local level (Green Deal, 2015; Gemeente Heerhugowaard, 2016; de Bruijn, 2017). Whether or not it is a result of these policies, it is a fact that carsharing is rapidly growing. Carsharing organizations Greenwheels and Car2go experienced an increase in reservations of respectively 10% (Berkman, 2017) and 24% (Car2go, 2017) in The Netherlands in 2017 and SnappCar reported a growth of 50% (SnappCar, 2017) in their working area, which also includes Denmark and Germany. Moreover, according to a study of TNS NIPO (de Gier, van Exel, & Maret, 2014), the potential market size is even larger: at the time, only 1% was using the shared car as a mobility tool, while 20% stated to be interested in the usage of a shared car. On top of the large number of potential users and the rapid growth, experts suggest that the rise of the self-driving car might further increase the use of shared cars (Frenken, 2016; Tillema, et al., 2017).

Let us first briefly describe what carsharing actually encloses. Carsharing (not to be confused with ridesharing or carpooling) is defined by the VNG[1] (2008) as the repeated and consecutive joint use of motor vehicles by agreement between natural persons and a provider or between natural persons themselves originated from more than one household. In contrast to classical car renting, there is thus no agreement per rental period, but per provider or per sharing group. As a result, the pick-up of such a car is not restricted to opening hours or office locations and cars can thus be picked up anytime and anywhere. Depending on the carsharing organization, cars have to be brought back to the origin (round-trip) or can be left at the destination (one-way) and tariffs for shared car usage mostly consist of a time and distance component. The underlying idea of carsharing is that people do no longer pay for car ownership, but only for car usage, which is often referred to as Mobility-as-a-Service (MaaS). As a result, fewer cars can be used more intensively, which lowers the parking time and the total car fleet of a country (Das, 2017). Moreover, research has shown that people on average lower their car usage when they become a carsharing participant (Nijland, van Meerkerk, & Hoen, 2015), and it is therefore believed that carsharing will lower the total car travel demand.

An important question to ask here is whether all the positive effects credited towards carsharing, are indeed true. Conclusions towards the effects of carsharing so far are mainly based on (mostly small) case studies in which carsharing participants are asked for their changed mobility behaviour (Shaheen & Rodier, 2005; Martin, Shaheen, & Lidicker, 2010; Martin & Shaheen, 2016; Giesel & Nobis, 2016; Le Vine & Polak, 2017). However, knowledge is lacking on how fellow citizens respond to their carsharing neighbours. Reduced congestion and reduced parking pressure are for example likely to encourage others to increase their car ownership and/or car travel demand and the positive effects of carsharing might thus be overestimated. Moreover, knowledge is lacking on the the number of carsharing participants in the future. In current studies, future expectations are often based on extrapolation of the experienced growth, but this does not account for saturation in the carsharing market. Other studies base their conclusions on surveys in which people are asked for their potential carsharing participation under hypothetical circumstances, but here a hypothetical bias comes in.

As a result of the growing nature of carsharing, the lack of knowledge on the effect of carsharing presence on non-carsharing participants, and the wish to gain better insights in future carsharing demand, **the need arises to model the effect of carsharing in strategic travel demand models.** Transport models are a systematic representation of the complex real world in terms of transport- and land-use systems (Department of Infrastructure and Regional Development [AU], 2016). Transport modelling is a powerful tool to determine long term effects of carsharing and to conduct scenario analyses.

Travel demand modelling for passenger transport is classically done in a so-called four-step model, see also Figure 2. The four steps include (1) trip generation, (2) trip distribution, (3) mode choice, and (4) route assignment. In the first step, the total number of incoming and outgoing trips per zone is determined. Trip distribution then matches the origins and destinations, resulting in the total number of trips per origin-destination (OD) pair. In the mode choice, the trips are then distributed over various modes and in the final step the trips are assigned to a certain route.

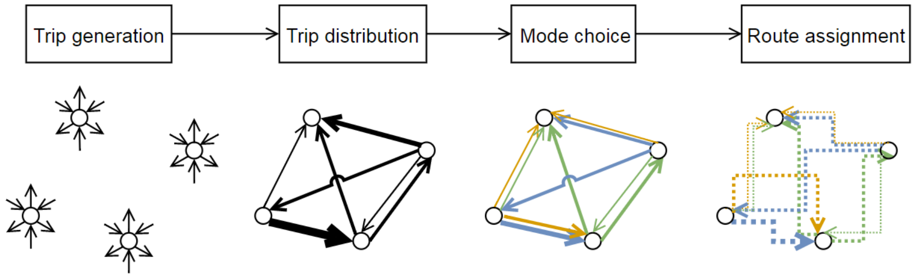


FIGURE 2: THE FOUR STEP MODEL

On top of these four steps, most of the strategic travel demand models are extended with a car ownership model of which the outcomes are used as input for the mode choice and sometimes also to trip generation and trip distribution (de Jong, et al., 2004). Car usage (and sometimes also trip frequency or destination choice) in most travel demand models thus depends on whether or not a private car is (freely) available in the household.

Here, a problem arises: **current car travel demand models do merely or not account for the usage of a car that is not owned by the household**, while carsharing enables households to use a car without owning one. It can however not be assumed that a shared car is available for anyone. In order to use a shared car, subscription for a carsharing organization is required and research has shown that the willingness to participate in carsharing programs is limited. This suggests that carsharing participation should be modelled separately, just as car ownership. At the same time, research showed that a causal interrelation is present among car ownership and carsharing participation (Becker, Loder, Schmid, & Axhausen, 2017): car ownership affects the willingness to become a carsharing member and vice versa. Car ownership and carsharing participation can thus not be considered as isolated topics.

This brings us to the research topic: **The joint modelling of carsharing participation and car ownership in strategic travel demand models.** The scope of the research is narrowed to **disaggregate** modelling, with the purpose to provide information on the **total number of cars** in the household and **the participation in a carsharing program**. Carsharing participation is here defined as the usage of a shared car at least once a year. Making the private car available for others via a carsharing platform is thus not considered as carsharing participation. For the empirical modelling, **revealed preference data** is used. The research moreover focusses on the **Dutch market** and uses the Dutch national strategic travel demand model (**LMS**[1]) as a case study. How the obtained information on car ownership and carsharing participation is processed in the mode choice, is outside the scope of this thesis and left for future research. A visual representation of the research scope is shown in Figure 3.

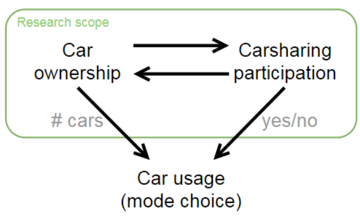


FIGURE 3: RESEARCH SCOPE

The study differs from previous research, because it considers carsharing and car ownership as the outcome of one single decision process, and because a disaggregate model is designed based on revealed preference data on a national level. Earlier empirical studies towards carsharing participation are mostly isolated models that use car ownership as endogenous explanatory variables (Celsor & Millard-Ball, 2007; Stillwater, Mokhtarian, &

[1] LMS: Landelijk Model Systeem [National model system].

Shaheen, 2009; Zheng, et al., 2009; Zhou & Kockelman, 2011; Coll, Vandersmissen, & Thériault, 2014; Blomme, 2016; Becker, Ciari, & Axhausen, 2016). In these studies, it is unanimously found that car ownership has a negative impact on the willingness to participate in a carsharing program. However, modelling from this point of view, disregards that car ownership and carsharing membership are both outcomes of the same underlying decision process (Mishra, et al., 2015). Moreover, much of the earlier work consists of aggregated regression models that aim to determine the carsharing adoption in a region (Celsor & Millard-Ball, 2007; Stillwater, et al., 2009; Coll, Vandersmissen, & Thériault, 2014; Hobrink, 2014; Blomme, 2016). Aggregate approaches however do not allow household-level socio-economic influences on behaviour to be presented (Fox, et al., 2016). The few disaggregated models that exist towards carsharing participation are mainly focussed on Stated Preference (SP) data in which respondents are asked for their willingness to participate in a hypothetical carsharing program (Zheng, et al., 2009; Zhou & Kockelman, 2011; de Luca & Di Pace, 2014; Kim, Rasouli, & Timmermans, 2017a; Kim, Rasouli, & Timmermans, 2017b). A major disadvantage of SP studies is the potential presence of biases. In SP studies, a respondent may state to choose an alternative, but then fail to do so due to strong habitual behaviour (Verplanken, Aarts, Knippenberg, & Moonen, 1998), a weak intention, or low actual behavioural control and optimism bias (Gärling & Fujii, 2002). Last, all disaggregated- and most aggregated work focusses on local study areas or large carsharing operation areas only.

An exception is the work of Becker, Loder, et al. (2017). In this study, carsharing participation is jointly modelled with car ownership, national- and local public transport subscriptions. Moreover, the model is estimated based on revealed preference data from the Swiss national travel surveys. The number of carsharing observations is however rather low (n=199) and as a result only few significant results were found and additional research is thus needed. Moreover, the study is conducted on an individual level, where car ownership is represented as 'acces to a car'. No distinction is made in whether the car is shared with other household members or not, while other studies showed that the availability of the private car impacts the willingness to participate in carsharing (Kim, et al., 2017a; Kim, et al., 2017b). The research in this thesis differs, because the total number of cars in a household is taken into account. Moreover, in this thesis it is aimed to construct a model that is suitable for implementation in a strategic travel demand model, while Becker, Loder, et al. (2017) merely aimed to construct an isolated model. It should be noted that this thesis does not account for interrelations with public transport memberships, although Becker, Loder, et al. (2017) found that common unobserved effects are present among all four mobility tools. Instead, this thesis merely focusses on car usage and the potential inclusion of public transport membership modelling is left for future research.

The earlier empirical studies that are described above have provided resourceful information on the consumers that opt for carsharing, which is further elaborated on in Chapter 3: Literature review on car ownership- and carsharing participation modelling.

1.1 Research objective & research questions

The research objective is twofold:

1. Understand which factors affect carsharing participation by estimating choice models;
2. Specify how a joint model for carsharing participation and car ownership could be incorporated in the Dutch national transport model (LMS)

This research thus encloses a design task and hence the final product is a design of an empirical model. To guide the research and to gain a deeper understanding a series of research questions are set up:

1. What does the current carsharing market in The Netherlands look like and what developments can be expected in the nearby future?
2. What are the factors that affect someone's willingness to become a carsharing participant or to purchase a car?
3. How to jointly model car ownership and carsharing participation from a conceptual point of view?

4. To what extent can the conceptual model be operationalized into an empirical model with the data that is currently available?
5. What will be the impact of (potential) future developments on the total carsharing participation?
6. What are the possibilities to incorporate a joint model for carsharing participation and car ownership in the Dutch national transport model (LMS)?

1.2 METHODOLOGY

To answer the sub questions and hence meet the research objective, a methodological framework is set-up, see also Figure 4. As can be seen, the research can be split in four parts: (1) Theoretical framework, (2) Conceptualisation, (3) Operationalization & Analysis and (4) Results and Evaluation. In the theoretical framework, that covers the first two research questions, literature is consulted and interviews are conducted to gain a better understanding of the carsharing market and to determine what explaining factor are found in earlier studies. In the conceptualization phase, the gained knowledge is converted into a conceptual model for car ownership and carsharing participation, in the form of a relationship diagram to answer the third research question. In the operationalization of the conceptual model, the hypotheses as formulated in the conceptual model are tested via empirical analysis. First a 'best possible model' is constructed with the data available. Next, the model is applied on various to test the impact of future developments. The operationalization phase concludes with the construction of the 'LMS best possible model', where the earlier empirical model is adapted, such that it fits in the LMS environment. In the Results and Evaluation phase the main conclusions are presented and the research is discussed.

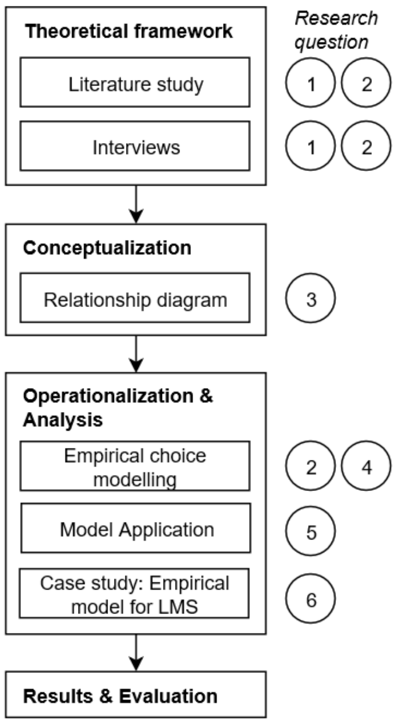


FIGURE 4: METHODOLOGICAL FRAMEWORK

Below, for each of the research questions, the used methods are presented and justified.

1. *What does the current carsharing market in The Netherlands look like and what developments can be expected in the nearby future?*

Knowledge of the carsharing market is primarily gained via **grey literature**: websites from organizations, press releases, newspaper reports and information spread via branche organizations. A strength of this form of data gathering, is that it ensures recent information. However, since most of these sources are written by people who are promoting carsharing and no peer reviews are conducted, the information might be biased. Information from organization's websites and press releases, might be presented more positive than it actually is and sensitive or negative information is often withholded. Therefore, **market surveys from independent research agencies** are looked into for information on more subjective/sensitive topics like perceived (dis)advantages and differences among carsharing user from differen organizations.

It was however found that literature felt short in certain topics (carsharing demand, user profiles, and future developments) and therefore **interviews** were planned with representatives from carsharing organizations. The employers of carsharing organizations are experts in the field and can provide information on the latest developments in the market, the business' plans in the nearby future, and the experiences from failures in the past. Furthermore sensitive data that is not shared via public canals (such as usage numbers, market share, user profiles), is more easily shared via an interview. The interviews are hold face-to-face, because this provides the richest data in terms of body language and non-verbal communication (Dingemanse, 2017b). Moreover, face-to-face was preferred, because the interviewees were unknown to the author at the moment of contacting, which creates distance and makes people cautious with providing information. The interviews are conducted in a semi-structured way. In this way, topics could be sent to the interviewee beforehand, while still being able to discuss emerging findings and not being held to a rigid structure (Dingemanse, 2017a). The weakness of the interviews lies in the fact that all persons talked to, are speaking on behalf of the organization they work for. This means that they have a certain bias towards their own organization and other competitors. Furthermore, they are cautious with sharing information that could harm the company. To tackle this problem, all interviewees were told beforehand that, if demanded, information could be used anonymously and that they could check the minutes of the interviews afterwards. Another weakness of interviews is the danger of bias in the way questions are asked. To reduce the bias, open questions were asked whenever possible, because these are least likely to bias answers (Farrell, 2016).

2. *What are the factors that affect someone's willingness to become a carsharing participant or to purchase a car?*

In order to answer this research question, both qualitative and quantitative research is conducted. First hypotheses on factors that explain car ownership or carsharing participation are formulated with the help of literature and interviews, which are then tested via empirical modelling. By first conducting qualitative research, over specification of the empirical model is prevented. Moreover, qualitative research provides information on variables that are not present in the quantitative dataset.

The literature that is used to formulate hypotheses, include **Dutch market surveys** from independent research agencies, **scientific literature on the empirical modelling** of carsharing participation and car ownership, and the **technical documentation reports** of the car ownership models that are currently used by the Dutch government. Literature is scarce on joint modelling, hence also models are reviewed that merely account for one of the two topics. Moreover, this thesis primarily focusses on the factors that explain carsharing participation and only briefly describes the factors that explain car ownership, since the latter one is a well researched field already.

Apart from literature study, the **interviews** (as already introduced above) were used to gain additional knowledge. The interviews are primarily used to validate whether explaining variables found in foreign literature are also representative for the Dutch carsharing market. Moreover, Greenwheels and MyWheels provided information on their users, which were underpinned with internal data analyses and surveys.

Information on how the **empirical analysis** is conducted to validate the findings from the interviews and literature, is provided in the accompanying chapter.

3. *How to jointly model car ownership and carsharing participation from a conceptual point of view?*

The conceptual model consists of the specification of the system boundaries and system elements (decision units) and provides insights in the expected explaining variables and the internal relations among these variables. The set-up of the conceptual model is thus a design question, which is answered by constructing a **causal relationship diagram**.

Causal relationship diagrams, or system diagrams, are powerful tools that help to understand and visualize complex systems. Such diagrams are particularly helpful in showing dynamic interconnections and help to see how a certain variable might impact other variables (Kim D. H., 1992). Because the decision for carsharing membership and car ownership is found to be impacted by numerous variables, that also impact each other, it is chosen to visualize these complexities by means of a causal relationship diagram.

4. *To what extent can the conceptual model be operationalized into an empirical model with the data that is currently available?*

In order to operationalize the conceptual model in an empirical model, sample data is needed. During this research it is chosen to use secondary data instead of newly collected data due to time and costs limitations. The data that is used is provided by TNS NIPO and originates from their carsharing monitor in 2014 (de Gier, et al., 2014). An exploration of the available data and its consequences on the set-up of the empirical model are discussed in the chapter that elaborates on the empirical model. In this chapter, also the modelling approach and the statistical software that is used, is elaborated on.

5. What will be the impact of (potential) future developments on the total carsharing participation?

This research question is answered via **model application**. The empirical model that is constructed, is applied to test the impact of various scenarios. Model application (or simulation) is a suitable method to analyse complex system that are affected by numerous variables.

6. *What are the possibilities incorporate a joint model for carsharing participation and car ownership in the Dutch national transport model (LMS)?*

To answer the final research question, a case study is conducted on the Dutch national transport model (LMS). First, **technical documentation** is consulted to determine how car ownership and carsharing participation influences other steps in the LMS and the position of a joint model for car ownership and carsharing participation is determined. Next, the national transport surveys are looked into to determine what variables are available in the LMS environment and the earlier empirical model is adjusted to account for the possibilities that are offered by the LMS. Then, a new empirical model (the LMS best possible model) is estimated and compared with the earlier estimated empirical model.

1.3 READING GUIDE

This report follows the structure of the methodology framework, see also Figure 5. In chapter 2 the carsharing market is further explored via qualitative literature and interviews. What is the size of the carsharing market, what variations exist in the carsharing product, who are the carsharing participants and what does their mobility behaviour look like? In chapter 3, existing literature towards the empirical modelling of carsharing participation and car ownership is reviewed, from which potential explaining variables are derived and in which modelling structures are evaluated. In the fourth chapter, the gained knowledge on carsharing participation is transferred into a conceptual model. Here, system boundaries are reconsidered, the appropriate decision unit for disaggregate modelling is determined and hypotheses are formulated for the relations among the variables. In chapter 5, it is aimed to operationalize the conceptual model into the best possible empirical model with the data that is provided for this research. Here, the available data is explored, the model structure is specified and a model is estimated. In chapter 6, the empirical model is applied to test various scenarios. In the 7th chapter, a new empirical model is designed that takes into account both the available data and the context of the Dutch strategic travel demand model (LMS). After the presentation of this 'LMS best possible model', the empirical model is compared to the earlier 'best possible model' and the conceptual model, and recommendations are given on how to adapt the LMS and/or the empirical model to better incorporate carsharing participation in the LMS. This thesis concludes with the answers on the research questions and a discussion.

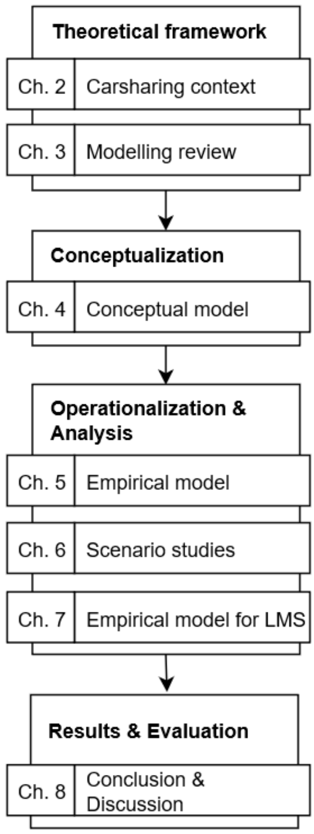


FIGURE 5: RESEARCH OUTLINE

CHAPTER 2

2 CONTEXT: THE CARSHARING MARKET

The aim of this chapter is to gain a better understanding of carsharing. What is carsharing; what does the carsharing product look like and who are the users? Moreover, this chapter explores how carsharing relates to car ownership and aims to map the expected future developments in the carsharing market. In order to answer these questions, a variety of literature sources are consulted. It was however found that literature felt short in certain topics and therefore representatives of a number of carsharing organizations are interviewed for additional information (Car2go, Greenwheels & MyWheels). The minutes of these interviews are attached in Appendix A.

A thorough understanding of the carsharing market is needed, to be able to put the research into perspective. Knowledge on the context is required to be able to set up a conceptual model and to interpret results in later steps of the research.

This chapter starts with an elaboration on the different carsharing types that are distinguished in literature and scopes down the research to a specific set of carsharing types. In the second paragraph, the market size is determined in terms of supply and demand. Third, the carsharing product is elaborated on. Here, the variety in service components among carsharing types and organizations is listed and the perceived service level of the general public is mapped. The fourth paragraph goes more into detail on the carsharing participants, where after the fifth paragraph explores the relation among carsharing participation and car ownership. The sixth and last paragraph presents the conclusions.

In this chapter there is often referred to the more mature German market. Germany is by Greenwheels and Car2go mentioned as an example of a more grown-up market, which is also affirmed in studies published by Boston Consultancy Group (Bert, et al., 2016) and Deloitte (Schiller, Scheidl, & Pottebaum, 2017). In Germany around 2.1% of the population is participating in B2C carsharing (Statista, 2017), while in The Netherlands the total number of carsharing participants (B2C and P2P) is estimated between 100.000 and 120.000 by both Greenwheels and Das (senior advisor in local climate policy and sustainable mobility at Rijkswaterstaat), which equals 0.6%.

2.1 DIFFERENT TYPES OF CARSHARING EXPLAINED

According to literature, a wide variety of carsharing types can be distinguished. In this paragraph, the various types are defined and boundaries are set for the types to study during this research.

Carsharing can be distinguished in four main categories, see also Figure 6 (CROW/KpVV, 2017). B2C carsharing includes all forms of carsharing that are offered by commercial organizations that have their own fleet of shared cars. Peer-to-peer (P2P) carsharing is a form of carsharing in which a car owner rents out his/her own car to peers via an online platform in exchange of a financial compensation. P2P platforms charge some mediation costs per rental to the car owner and/or the car user and often provide auxiliary services like insurance (Shaheen, Mallery, & Kingsley, 2012). Carsharing via local communities is also a way of carsharing between peers, but in this case the car is owned by a group of households and only shared within the group. Business carsharing is when employees make use of shared cars that are provided by the employer; sometimes via a third party that functions as a fleet owner and is in control of the fleet management.

Within B2C-carsharing, various subcategories are present. Round-trip and one-way carsharing differ in the spot where the car can be left after usage (CROW/KpVV, 2017). In contrast to round-trip carsharing, one-way carsharing offers possibilities to leave the car at the destination. One-way carsharing can either be free-floating or station-based (Shaheen, Chan, & Micheaux, 2015). Free-floating enables the user to leave the car at any place within the operating area; while station-based only offers a limited number of predetermined locations.

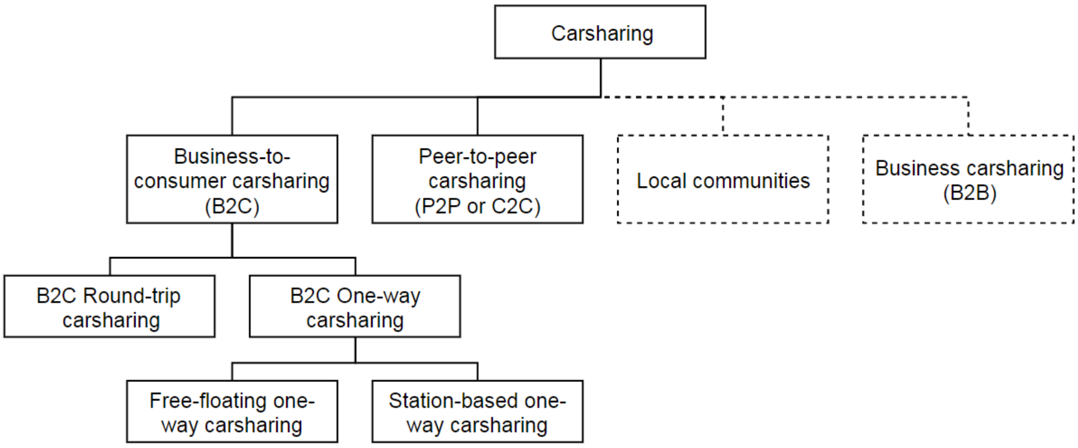


FIGURE 6: DIFFERENT TYPES OF CARSHARING. CARSHARING TYPES WITHIN DOTTED LINES ARE OUTSIDE THE SCOPE OF THIS RESEARCH

Theoretically, one could categorize any type of carsharing into round-trip or one-way and into free-floating or station-based. However, in this report these terms refer to the B2C alternatives.

In this study the focus lies on the carsharing types, of which participation is decided within the household: B2C- and P2P-carsharing. Business carsharing is considered as a joint decision of the employer and the employee and carsharing via a local community involves multiple households.

2.2 CARSHARING SUPPLY AND DEMAND

This paragraph describes the supply and demand of P2P- and B2C carsharing. The aim of this paragraph is to put the various carsharing types into perspective, explore regional differences and to distinguish the major market players. To do so, first the supply side is elaborated on, after which the car sharing demand is discussed.

2.2.1 SUPPLY OF SHARED CARS

Table 1 shows an overview of the development of the supply of shared cars in the period of 2012-2017. The numbers are collected by CROW/KpVV in March of the corresponding year. As can be seen in the table, the supply of P2P carsharing is rapidly growing and accounts for 89.8% of the total shared car supply in 2017. Moreover, one can observe that the supply of round-trip carsharing is around five times larger than of one-way carsharing. The supply of round-trip shared cars is more or less constant, although the last few years a growth can be seen. In the supply development of one-way shared cars, a turning point can be seen between 2014 and 2015.

TABLE 1: SUPPLY OF SHARED CARS IN ABSOLUTE NUMBERS IN THE PERIOD OF 2012-2017. ADAPTED FROM (CROW/KPVV, 2017)

Carsharing type	2012	2013	2014	2015	2016	2017	% in 2017
Round-trip carsharing	2,139	2,082	2,154	2,103	2,278	2,385	8.6%
One-way carsharing	300	300	300	415	414	441	1.6%
P2P carsharing	396	2,463	8,142	11,100	18,922	24,779	89.9%
Total	2,835	4,845	10,596	13,618	21,614	27,605	100%

According to more detailed information from CROW/KpVV (2017), round-trip carsharing is primarily provided by Greenwheels (71% of the supply), followed by Connectcar (14%) and MyWheels (8%). The providers that represent the remaining 7%, are (in alphabetic order) CareCar, Deelootoo, Drive, Elektrip, Flexcar, Free2Go, Hertz 24/7, Hoppa, MobielGedeeld, SharedWheels, Stapp-In and StudentCar. Round-trip shared cars can be found all over the country, although cars of certain providers are only available in selected areas. Furthermore, the supply is primarily concentrated in densely populated areas. In particular outside the Randstad there numerous villages can be found, where no round-trip shared car is available.

The market of one-way carsharing is less shattered; Car2go is the major supplier (79%) and is a free-floating organization in Amsterdam (CROW/KpVV, 2017). Since 2015, also other one-way providers have entered the market. Witkar (11%) offers both station-based as free-floating carsharing: they have pick-up and drop-off points in various cities in The Netherlands and have been providing free-floating shared cars in Rotterdam since 2015 and in Groningen since 2017. WattCar (10% of the market in 2017) provided its free-floating services in Terschelling in the period of 2015-2018, but recently went bankrupt (Kuijpers, 2018). In October 2017, a new competitor entered the market: IONIQ Carsharing (Hyundai, 2017). IONIQ Carsharing provides 100 free-floating cars in Amsterdam.

In the P2P market, SnappCar is the clear market leader in terms of supply (90%), followed by MyWheels (9%). The remaining cars are offered via the online platforms DayCar, TrexCar and ParkFlyRent. P2P shared cars are available in every municipality in The Netherlands.

2.2.2 DEMAND FOR SHARED CARS

Numbers on the actual usage of shared cars are scarce in The Netherlands. For the major provider of each carsharing type, the information available is collected in Appendix A and the results are summarized in Table 2.

TABLE 2: OVERVIEW OF USAGE OF SHARED CARS OF THE MAJOR PROVIDERS IN THE NETHERLANDS

Provider	Supply [#]	Share of total supply [%]	Trips per year [#]	Average trip length [km]	Average trip time	Estimated yearly demand [km]
SnappCar	22300	90% in P2P market	Ca. 40,000[2] (Aug '16 – Aug '17)	230 km	1.5 days May-August: 4-5 days	9,200,000
Greenwheels	1700	71% in round-trip market	350,000 – 400,000 (Oct '17)	45 – 50 km	5h43m (Aug '17)	17,820,000
Car2go	350	79% in one-way market	Ca. 990,000[3] (Jan '17)	5.3 – 7 km	20min (2017)	6,090,000

Table 2 shows rather varying trip characteristics per organization. The differences can partly be explained by the carsharing type; when the car has to be brought back to the origin, the trip is per definition longer than a trip with a car that can be left at the destination. Another cause can be found in the varying working areas of the carsharing organizations. Car2go does not allow their users to drive the car outside The Netherlands. In case of Greenwheels, permission should be requested to travel outside the Dutch borders, but it is explicitly stated on their website that their cars are not equipped for winter conditions. In contrast, cars of SnappCar can be driven anywhere.

To verify whether the differences in trip characteristics between the organizations are representative for the carsharing types in general, MyWheels is consulted. MyWheels is an organization offering both P2P-carsharing and round-trip carsharing. In the interview (Appendix A), MyWheels affirmed that a difference in trip length is present, but indicated that this is mainly the result of the car access (key exchange or entrance via

[2] It should be emphasized that this number is rather unsure; since it is concluded based on many assumptions, see also Appendix B.
[3] The number is expected to be at least 732,000 and max 1,350,000.

smartcard/app). Privately owned cars that can be opened via a smart-card are experienced to be used for shorter trip distances.

Another conclusion that can be drawn from Table 2 is that the supply of shared cars is a rather poor indicator of the actual usage of a specific carsharing type. The table shows that most carsharing kilometres are driven with a Greenwheels car, followed by SnappCar and then Car2go. Looking solely at the number of bookings, Car2go is the major provider.

To get an idea of the total demand per carsharing type, Table 3 shows an approximation based on an extrapolation of the numbers presented in Table 2. To determine the approximated carsharing demand, the total kilometres travelled per organization are divided by the organization's share in the total supply of their corresponding submarket, according to CROW/KpVV (2017). In this calculation, it is thus assumed that all shared cars of the same carsharing type are used equally intensive. The total carsharing demand as approximated in Table 3, equals 0.02% of the total travel demand in The Netherlands in 2016, which is estimated on 194.9 billion in 2016 (CBS, 2017f). In comparison, the total number of car kilometres in 2016 equalled 140.8 billion. Carsharing thus only accounts for a marginal part of the total car travel demand (0.03%).

TABLE 3: APPROXIMATED CARSHARING DEMAND PER CARSHARING TYPE

Carsharing type	Approximated carsharing demand [km]
P2P carsharing	10,200,000
Round-trip carsharing	25,100,000
One-way carsharing	7,710,000
Total	43,010,000

2.2.3 FUTURE SUPPLY AND DEMAND

Researchers around Europe in general agree that the carsharing market is expected to grow (Frenken, 2013; Bert, et al, 2016). How the different carsharing types will relate towards each other in the future, is however still unexplored territory. During the interviews with varying carsharing organizations (Appendix A), it was found that organizations aim to prepare themselves for varying scenarios: MyWheels is investing in both round-trip and P2P carsharing, and Greenwheels has the wish to also offer one-way carsharing on the longer term.

Looking at foreign countries, it is seen that one-way carsharing is booming. In both Germany and Italy, one-way carsharing is the most used carsharing type. Moreover, according to a French study one-way carsharing is still new and its benefits may be more evident in the future (6t, 2014). On top of that, many worldwide experts anticipate growth in one-way carsharing to continue (Shaheen & Cohen, 2013). Whether the foreign countries are representative for The Netherlands is questionable. It is however a fact that the possibilities towards one-way carsharing between the G4-cities[4] are explored on the moment (Gemeente Utrecht, 2017).

2.3 THE PRODUCT: THE SHARED CAR

The carsharing product consists of two parts: the service provided by the organization and the car itself. A variation in service or car type often comes with altered costs. In this paragraph the versatility of the product is explored. To what extent does the product vary among the carsharing types and among the organizations and what costs are related to this? Moreover, this paragraph will discuss the expected product developments towards the future. Knowledge on the versatility in the carsharing market helps to understand why people might prefer a certain organization or carsharing type over the other. Knowledge on the future market helps to learn to what extent differences between the carsharing types will increase or decrease.

[4] G4 refers to the four largest cities in the Netherlands: Amsterdam, Den Haag, Rotterdam & Utrecht.

This paragraph will first discuss the variation in service level and service related costs. Next, the variation in car types and usage costs are elaborated on. Last, insights on future developments are presented.

2.3.1 Variation in service level and service related costs

Table 4 shows for the two major organizations of each carsharing type the variation in service components. The information is collected from the company's websites[5] and last updated in March 2018. It should be noted that most organizations have changed their membership structures over the last years and it can therefore occur that current members have deviant conditions in their contract. Below, first the most striking differences among the carsharing types are discussed, where after the organizations within the same carsharing type are compared.

TABLE 4: VARIATION IN SERVICE COMPONENTS AND RELATED COSTS AMONG CARSHARING ORGANIZATIONS

Component	Car2go	IONIQ carsharing	Greenwheels	ConnectCar	SnappCar	MyWheels
Carsharing type	One-way	One-way	Round-trip	Round-trip	P2P	P2P
Subscription	Mobile application	Mobile application	Website, mobile application	Website, mobile application	Website, mobile application	Website, mobile application
One-time subscription fee	€9 (includes €15 credit)	€10	n/a	€25	n/a	n/a
Monthly costs	n/a	n/a	€0; €10; €25	n/a	n/a	n/a
Max. number of drivers per subscription	1	1	1; 2; 3	1	1	1
Reservation systems	Mobile application	Mobile application	Website; mobile application	Website; mobile application; phone	Website, mobile application	Website, mobile application
Reservation moment	0-20 minutes in advance	0-30 minutes in advance	Not restricted	Not restricted	Not restricted	Not restricted
Car access systems	Mobile application	Mobile application	Smartcard; mobile application	Mobile application	Key exchange	Key exchange; Smartcard; mobile application*
Fleet variety	1	1	3	2	>100	>100
Minimum age	18	18	18	18	21-25*	18
Surcharge for people under 25	n/a	n/a	n/a	n/a	€5 per day	+ €250 deductible excess
Minimum time driving licence	1	1	0	0	1	0
Deposit	n/a	n/a	€225	€100	n/a	n/a
Deductible excess	€500	€250	€350	€0	€750 - €1250*	€250
Buy off deductible excess	€9.90 per month	n/a	€4 per trip	n/a	€17.50 - €37.50 per day*	€3.50 per day (obligatory)
Deductible excess after buy off*	€0	n/a	€75	n/a	€250	€0
Minimum age to buy off deductible excess	n/a	n/a	n/a	n/a	27	n/a
Reservation costs	n/a	n/a	n/a	€3.50	10% of rental costs	€2.50
Minimum rental period	1 minute	1 minute	15 minutes	1 hour	8 hours (0.75 day) - 1 day*	15 minutes - 1 day*

*** Differs per car**

[5] www.Car2go.com/NL/nl/; www.ioniqcarsharing.nl/; www.Greenwheels.com/nl/; www.connectcar.nl; www.SnappCar.nl; www.MyWheels.nl

The major differences between the carsharing types are the (1) reservation- and subscription systems, (2) the minimum rental period, (3) the car access systems, (4) the age requirements, and the (5) membership costs. As a result of these variations, one-way carsharing is the preferred alternative for short trips. Moreover it is in the nature of one-way carsharing to be primarily interesting for one-way trips within the working area, especially when parking tariffs are high at destination. Downsides of one-way carsharing are the uncertain access time towards the nearest car and the fact that it is only accessible for people who have a smartphone with internet connection. Round-trip carsharing is convenient for people who want to be able to book a car in advance and is moreover accessible for unexperienced and/or young drivers. Downsides of round-trip carsharing are the relatively high start-up costs for deposit, registration fee and/or monthly membership costs. In contrast, P2P carsharing does not ask any start-up costs and is therefore most accessible for a try-out. Besides, P2P carsharing offers a large fleet variety. Downsides of P2P carsharing include the limited pick up moments as a result of an often needed key exchange and the surcharges that apply for people under 25. Moreover, the booking time depends on the responsiveness of the car owner and whether or not the first one approached also accepts the booking.

Also between organizations of the same carsharing type, variations exist. As can be seen in Table 4, the two one-way carsharing organizations are rather similar in their services; they only vary slightly in their subscription fee and insurance conditions. Among the two major round-trip organizations (Greenwheels & ConnectCar), the variations are larger. Greenwheels has various membership plans that have to be paid for per month, while ConnectCar only has a one-time subscription fee. At the same time, ConnectCar requires reservation costs per trip. Moreover, Greenwheels charges a deductible excess in case of damage and offers the possibility to open the car via a smartcard. Between the P2P organizations, the major difference is the deductible access and the minimum age. At SnappCar, the deductible access is much higher than at MyWheels, just as the buy off. Moreover, at SnappCar it is not possible to rent a car under the age of 21, and even then many cars are still unavailable, depending on the car owner. Last, at MyWheels some cars can be opened via smartcard and be booked from 15 minutes onwards, but in practice for most cars still a key exchange is needed and the minimum rental period is often set to 1 day.

2.3.2 Variation in car types and car type related costs

Table 5 shows the variation in car types among the B2C carsharing types. It is seen that the fleet variety differs among the different carsharing types: one-way organizations only offer one type of car, while round-trip organizations let their members choose between a small selection suitable for different trip purposes. P2P carsharing is not included in the table, because over 100 different types are available via P2P carsharing platforms. The cars at the P2P platforms vary from electric Tesla's and old-timer campervans to the 'regular' types that are also offered by the B2C organizations.

TABLE 5: VARIATION IN CAR CHARACTERISTICS AMONG B2C CARSHARING ORGANIZATIONS

Components	Car2go	IONIQ carsharing	Greenwheels	ConnectCar
Carsharing type	One-way	One-way	Round-trip	Round-trip
Car type	Smart ForTwo	Hyundai IONIQ	Volkswagen Up!; Volkswagen Golf; Volkswagen Caddy	Smart ForFour; Opel Zafira (only in Amsterdam)
Operation	Automatic	Automatic	Manual	Manual; Automatic
Power	Electric	Electric	Fuel	Fuel
Radius of action	Max 160km	Max 280km	n/a	n/a
Number of seats	2	5	4; 5; 2	4; 7
Size	A-segment	C-segment	A-segment; C-segment; M-segment (minivan);	B-segment; M-segment (D)

Looking at the differences between the two B2C organizations, one can see some major differences apart from the fleet variety. In contrast to the round-trip cars, the cars of Car2go and IONIQ are electric and have a limited radius of action. The radius of action denoted in the table represents the maximum, when the battery is fully loaded, which is often not the case. Moreover, the electric one-way cars have automatic operation, while the round-trip cars are mostly manually operated. It should be noted that this strict separation is not representative for all one-way and round-trip organizations. Witkar for example offers fuel-driven and manually operated cars for one-way carsharing and some of the smaller round-trip organizations (also) offer electric vehicles.

The varying car types come at varying costs. An overview of the costs per organization and per car type is attached in Appendix C. Based on the costs overview one can conclude that **clear differences exists in the cost structures among the various carsharing types**. Usage costs for one-way carsharing are usually only based on a time component, while in case of round-trip and P2P-carsharing also a distance component is taken into account. Moreover, B2C organizations often give discounts for longer time periods, while the costs of P2P carsharing develop linearly in time. Nevertheless, P2P charges the lowest costs per time-unit. P2P carsharing is however not per definition cheaper, because they charge a minimal rental time and/or relatively high start-up costs. As a result of the varying costs structures, one-way carsharing is primarily financially attractive for trips in which a relatively high amount of kilometres are driven per time-unit. Round-trip carsharing is most appealing on short trips that include parking time of 1 or 2 hours (such as grocery shopping). P2P carsharing is clearly cheaper on the longer trips, due to relatively low usage costs per kilometre and per time-unit, but rather high start-up costs.

2.3.3 Observed and expected developments in the carsharing product

Figure 7 shows the observed and expected developments in the carsharing product. The developments in the orange blocks represent expected changes in the carsharing supply and demand and are based on findings in paragraph 2.2.3, the grey blocks represent developments in the carsharing product itself, which are further elaborated on in this paragraph. The developments in the past are based on old websites of carsharing organizations that are consulted via an internet archive database (https://web.archive.org/) and interviews with representatives from carsharing organizations (Appendix A). The interviews also functioned as a guideline for the expected future developments, which are further supplemented with elements based on the more mature German carsharing market (Appendix D).

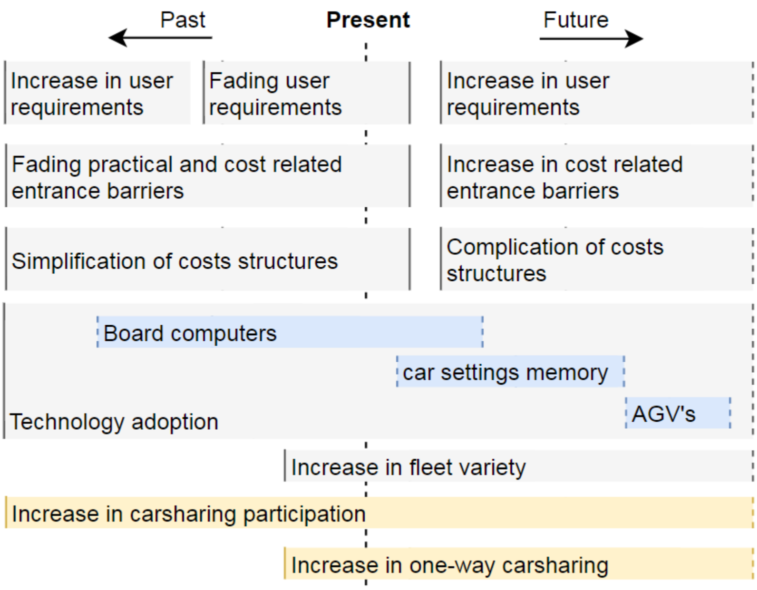


FIGURE 7: OBSERVED DEVELOPMENTS AND EXPECTED TRENDS IN THE CARSHARING PRODUCT

Below, the developments that are illustrated in the grey boxes in Figure 7 are elaborated:

- **User requirements**

Requirements can be set on the driving experience and/or age of the carsharing participant, usually with the aim to reduce damage and insurance costs. Over the last couple of years, some changes can be seen. The major carsharing provider (Greenwheels) accepted both young and inexperienced drivers in the beginning, but then set age requirements in 2009 (Rezelman, 2016). Since 2016, these age requirements however have disappeared, which is likely to be a response on a number of new market players that set lower user requirements. Overall, carsharing has become more accessible for young and inexperienced drivers over the last few years.

It is highly questioned whether this observed trend of lowering user requirements will set through, primarily because it is strongly related to decisions of competitors. So far, the user requirements at P2P organizations (see Table 4) have not changed, although at SnappCar this is partly determined by the car owner. Moreover, according to the interviews, Greenwheels and MyWheels are currently looking for a way to set up a 'black list' together to prevent misbehaving users to hop on to the next organization. Besides, lowering user requirements is not a trend that is reflected in foreign countries. Drive-now users in whole Europe have to be at least 21 and have to possess their driving licence at least one year[6]. In the more mature German market, carsharing organizations are also found to set user requirements or let their younger members only use cheaper car types (See also Appendix D).

- **Entrance barriers**

The entrance barriers are the obstacles that have to be overcome while registering for a carsharing organization. Over the last years, it is seen that subscription process has become easier and faster: at all organizations studied it is currently possible to drive a shared car within a few minutes after online registration and it is no longer needed to send contracts by post or to wait for membership cards. Moreover, most organizations offer the possibility to subscribe via a mobile application. It should be noted that exceptions apply for people who caused large damage by car over the past few years. Apart from practical barriers, there are also cost barriers, such as a registration fee, a required deposit or monthly membership costs. During the interviews it is found that also these barriers are lowering. Greenwheels has added a membership structure in which no monthly costs have to be paid and MyWheels dropped its monthly membership costs and deposit completely.

For the practical barriers, it is assumed that optimization is more or less reached. Regarding the cost-related entrance barriers, further reduction is still possible, but it is expected that a turning point will come. Lowering the cost related entrance barriers is typically needed in markets where the service is not well known yet. In a more mature market it is not an unordinary thought that the administration fee will find their way back into the cost structures, assuming it is less of a problem to pay start-up costs, when one already knows the provided services will meet ones demands. In Germany it is for example seen that registration fees are higher.

- **Cost structures**

It is remarkable that all carsharing organizations interviewed, have changed their cost structures (several times) over the last few years (See Appendix A). In general, all adaptions have led to a simplification of the cost structure: Car2go no longer distinguishes separate parking- and driving costs, Greenwheels now combines maintenance and fuel costs per kilometre, and MyWheels no longer offers varying membership structures with varying prices per kilometre.

It is not expected that the simplification in cost structures will set through. Instead, more complicated cost structures are expected. Looking at the public transport- and telecom industry, it can be seen that an increased usage comes with a higher variety in membership structures and package deals. In Germany, it is also seen that the cost structures are more varied (Appendix D). Usage costs here differ per time of day and surcharges are

[6] According to their website, visited in March 2018: https://www.drive-now.com/en/

calculated for specific locations. Moreover, a higher variety of package deals exist, travel credit can be purchased in advance, and memberships for a certain number of hours per month are available.

- **Technology adaption**

Various innovations have found their way to the carsharing market, among which navigation systems, air-conditioning, and rear view cameras. It can be expected that also towards the future innovations in the car market in general will be adopted in shared cars. In the light of carsharing there is however a shortlist that requires special attention: (1) Board computers, (2) Automatic driver adaption, and (3) Automated Guided Vehicles (AGV's).

Board computers enable car access by phone or smartcard. Besides, the board computer automatically sends the trip time and trip distance to the organization to determine the costs. In contrast, for the access of most P2P cars, key exchange with the owner is still needed and times and distances have to be filled in manually. An interesting technology development in this context is MyWheels Open (See interview MyWheels, Appendix A). MyWheels Open is a board computer that can be installed in private cars, whereby key exchange and manual trip logging is not needed anymore. According to MyWheels, the board computer increases the hire of privately owned cars, while the average rental time decreases. Car owners now also accept short bookings, and can have multiple bookings in a row without staying at home. It is expected that it is only a matter of time before SnappCar will offer a similar system. At the same time, the first consumer car is already produced with a pre-built board computer that enables carsharing: the newest Tesla model 3 (Snyder, 2017). The owner can give somebody else access to the car via mobile phone.

Another interesting feature in the Tesla model 3, is the automatic driver adaption. The car automatically adapts its settings to the preferred car settings of the driver, who is recognized via his/her mobile phone. Currently the preferred car setting are stored in the car's computer memory, but this will soon be moved to the cloud (Musk, 2017), which basically means that any Tesla you drive in the world, will adapt to your preferences. Such automatic driver adaption is expected to further lower the reluctance to carsharing: mirrors and seats do not have to be adapted anymore every time you use a shared car.

The last technology adaption that is expected to impact carsharing is the self-driving car. Currently, cars are not self-driving and it is unsure when (or even whether) this will happen. However, if cars will once become completely self-driving, it is assumed that this will have severe impact on carsharing. Frenken (2016) states that carsharing is becoming more attractive when vehicles can move themselves between various passengers. In a study of KIM towards various future scenarios with AGVs, it is suggested that P2P carsharing might grow particularly between friends and family and that the shared car of organizations will become part of an integrated multimodal transport system (Tillema, et al., 2017).

- **Fleet variety**

In the Dutch carsharing market, the variety in car types per B2C organization is limited. Since 2011, Greenwheels has expanded its fleet with minivans and medium-sized cars, but most other B2C organizations still offer only one type of car. Moreover, Greenwheels stated that they wish to offer electric vehicles (again) on the long term. They did so in the past, but then it was not yet financially feasible.

A more varied fleet is a logical result of a bigger (and thus more varied) customer database. Looking at a more grown-up market (Germany), it is therefore also seen that the fleet variety is higher. The German carsharing organizations Car2go, DriveNow and Flinkster offer respectively 5, 11 or 8 car types, although the number may be lower in certain cities. Moreover, all three major organizations in Germany offer both electric- as fuel powered cars. The fleet variety is thus expected to grow with the carsharing demand.

2.4 The customer: characteristics and mobility behaviour of carsharing participants

So far, we have seen the supply and demand of carsharing, the variety in service levels and the latest trends and developments. This paragraph aims to describe the customer. How do carsharing participants differ from the average population and what differences exist among participants of varying carsharing types in terms of demographics and mobility behaviour?

In this paragraph, first user profiles of the organizations interviewed are presented. Next, characteristics of carsharing participants as found in independent market surveys are presented, where after the mobility behaviour of the carsharing participants is elaborated on.

2.4.1 User profiles of interviewed organizations

During the interviews with Car2go, Greenwheels and MyWheels (Appendix A), the user profiles of the organizations are discussed. The highlights of these interviews are denoted below and illustrated in Figure 8.

FIGURE 8: USER PROFILES OF CARSHARING ORGANIZATIONS BASED ON INTERVIEWS WITH ORGANIZATION'S REPRESENTATIVES

Both MyWheels as Greenwheels indicated that their customers received on average a higher education and had higher household incomes than the general public. As can be expected from people with higher household incomes, Greenwheels also found that their customers are more often part of two-earner households and are living in more expensive houses than the average Dutchman. Furthermore, Greenwheels members more often live in apartments and canal houses, and probably thus more often in urban areas. Last, Greenwheels stated that their members are more often singles or families with (older) children and less often elderly than represented in the average Dutch population. MyWheels by contrast has a relatively old user group, although singles and families with kids are also well represented. Another contrast between the user groups is the car ownership; Greenwheels users are more than three times as likely to have a car in their household as MyWheels users, although in both cases the car ownership levels are below average. Cars of Greenwheels users are relatively young and more often in the small to mid-segment.

Car2go neither confirms nor denies that their members are highly educated or receiving high incomes. The only socio-demographic information provided is that their users are more often men. Car2go does however give some more information on the travel behaviour of their users compared to the average population. Car2go participants are more often using the train as their main transport mode, are less likely to own a car and experience shortcomings in the public transport network. Among their members, Car2go experiences a shift towards usage for business purposes and a user group that is lowering in age.

MyWheels is an organization offering both P2P-carsharing and B2C-carsharing and has been questioned about the differences between the two types of users. MyWheels could not provide demographic differences, but stated that there are only few people using both P2P- and round-trip carsharing, although it can be booked via the same platform. This indicates that most users thus have a clear preference for one of the two types.

2.4.2 CHARACTERISTICS OF CARSHARING PARTICIPANTS ACCORDING TO MARKET SURVEYS

The previous paragraph showed the user profiles of some carsharing organizations, but does not give a complete view, nor enables to make a valid comparison between carsharing types. Below, the two major market surveys that are conducted in the Netherlands are discussed. Table 6 shows the differences between carsharing participants and the average population according to these studies and Table 7 highlights the differences between B2C- and P2P carsharing participants.

The first study that is consulted is conducted by research bureau SmartAgent (2011) and commissioned by the municipality of Utrecht. For this study, inhabitants of the province of Utrecht are questioned (n=1040) and an extra sample is taken in which members of Greenwheels (round-trip), Wheels4All (nowadays called MyWheels – round-trip & P2P), StudentCar (round-trip) and the 'Vereniging voor Gedeeld Autogebruik[7] (local communities) are surveyed (n=453). One-way carsharing did not exist in The Netherlands at the time the survey was conducted. It should be noted that there were only seven respondents questioned in the local community's category, which implies that the effect of this group on the survey outcomes is rather small.

The second study is a report published by the KiM (Jorritsma, Harms, & Berveling, 2015), in which data is analysed that was collected by TNS NIPO (de Gier, et al., 2014). For this study, both carsharing participants and non-carsharing participants were questioned that were randomly selected from the TNS NIPO panel. There is thus no focus on a specific carsharing organization. In this study, carsharing participants are defined as people who made use of one-way-, round-trip-, or P2P carsharing at least once in the past year. People who rent out their own car via P2P platforms, are also considered as P2P carsharing participants.

As can be seen in Table 6, the two studies do not contradict each other in their profile sketch of carsharing participants. Moreover, findings are in line with the user profiles derived from the interviews. Contradictions do however show when looking at the differentiation between P2P-carsharers and B2C-carsharers, see also Table 7. This might be explained because the comparison made in the first study, is actually a comparison between Greenwheels (round-trip) and Wheels4All (round-trip & P2P) and thus rather an organization specific comparison. The differences among P2P and B2C carsharing participants imply that somebody who is willing to participate in B2C-carsharing, might not be open to P2P-carsharing.

TABLE 6: CARSHARING PARTICIPANTS COMPARED TO THE AVERAGE POPULATION (SMARTAGENT, 2011; JORRITSMA, ET AL., 2015)

Study	SmartAgent (2011)	Jorritsma, et al. (2015)
Carsharing type	Round-trip, P2P (only users) and local communities	Round-trip, one-way and P2P (users and car owners)
Carsharing participants are more often …	… highly educated … Groenlinks voters … member of a political party … member of an environmental organization … in the age of 25-44 … readers of Volkskrant, NRC Handelsblad, Trouw, de Pers and NRC.Next … active on LinkedIn and Facebook	… highly educated … earning above average incomes … people between 18-40 who are living in single households … people between 50-64 who live in two-persons households … people with a high social-economic status … living in highly urbanized regions
Carsharing participants are less often …	… VVD voters … Readers of De Telegraaf … Active on Hyves and online games … people who attach value to car ownership	… living in low urbanized regions

[7] The 'Vereniging voor Gedeeld Autogebruik' is Dutch for the 'Association of shared car usage' and is an organization that supports carsharing via local communities (for a description, see paragraph 2.1).

TABLE 7: P2P-CARSHARING PARTICIPANTS COMPARED TO B2C CARSHARING PARTICIPANTS

	Compared to round-trip carsharing participants (SmartAgent, 2011)*	Compared to B2C carsharing participants (Jorritsma, et al., 2015)
P2P carsharing participants are…	… older … less often living in highly urbanized regions … more often living in households with children	… younger … less often living in highly urbanized regions … more often people up to 35 years, who are living in single households … more often woman … receiving lower incomes … lower educated … more often people who own a car

***SmartAgent compared Wheels4All (P2P & round-trip) users to Greenwheels (round-trip) users, rather than P2P to B2C.**

In the market surveys discussed above, no differences between one-way and round-trip carsharing are mentioned. In the interviews, both Greenwheels and Car2go stated that their members are sometimes a member at various organizations (See Appendix A). It sounds plausible that B2C-users are simply making the decisions based on the trip characteristics; however, based on this information, one cannot conclude this with certainty. Nevertheless, it is a fact that the kick-off of Car2go in Amsterdam resulted in a strong growth in the demand for Greenwheels cars (Berkman, 2017).

2.4.3 MOBILITY BEHAVIOUR OF CARSHARING PARTICIPANTS

Carsharing participants are found to have a deviating mobility pattern compared to the general public and are also found to change their mobility usage after they start participating in carsharing.

According to SmartAgent (2011), Utrecht carsharing participants use the car less and the bike, 'OV fiets'[8], and public transport (primarily the train) more than the average Utrecht resident does. The study of TNS NIPO affirms the findings regarding car-, bike- and PT usage on a national level and moreover shows that carsharing participants make more trips (by any mode) than the general public (de Gier, et al., 2014).

When carsharing participants use the shared car, it is found that distances are on average longer than in case of private car usage (de Gier, et al., 2014). Carsharing is found to be primarily popular in the weekends (40% of the trips) and has its usage peak around 10/11 AM. Moreover, the shared car is often used for incidental trips and hence only used a number of times per year. Only few carsharing participants were found to use the shared car more than once a week. The shared car is most often used for a daytrip, followed by a family visit.

Nijland, et al. (2015) studied the changed mobility behaviour as a results of carsharing participation and found that car usage on average reduced with 4 to 32%[9], which is mainly caused by the people who shed their private car. Of all carsharing kilometres, it is estimated that 39% was formerly travelled by public transport, 38% by another car (private or rented), and 16% of the kilometres were not travelled at all. The remaining kilometres were travelled by other transport modes. It should however be emphasized that the results are based on a small sample, which impacts the validity of the results.

A more extensive survey among the Dutch Car2go users reveals some more information on changed mobility behaviour (Suiker & van den Elshout, 2013). The Car2go members were asked for their usage of other transport modes and here it was found that over 60% of the Car2go users make less use of public transport than they did before they started carsharing. Moreover, 34% stated to use the car less often, 28% is not using the taxi as much

[8] OV-fiets [PT-bike]. The OV-fiets is a rental bicycle that is available at most train stations in the Netherlands.

[9] Due to a small sample, the 95% confidence interval is rather large.

as before, and 27% is less often travelling by bike. These findings imply that one-way carsharing is rather an alternative for public transport than for private car usage.

2.5 Carsharing membership in relation to car ownership

In this paragraph it is aimed to better understand the relation between carsharing participation and car ownership. The previous paragraph already showed that carsharing participants own less cars on average, but so far it is not known what makes that some people buy a car, while others share a car.

In this paragraph, first the major (perceived) differences between a shared car and a private car are looked into. Next, a cost comparison is made to determine the most economically alternative for varying yearly mileages.

2.5.1 Perceived advantages and disadvantages of carsharing compared to car ownership

Table 8 provides an overview of the experienced and perceived advantages and disadvantages of carsharing compared to car ownership, according to numerous studies (SmartAgent, 2011; de Gier, et al., 2014; Shaheen, et al., 2015; ter Berg & Schothorst, 2015).

From the table, it shows that carsharing is primarily seen as **carefree** compared to car ownership: one is no longer responsible for the administration, maintenance and parking permits and (in case of B2C carsharing) cars are always in good state. Moreover there are little to no fixed costs. However, carsharing also brings in uncertainty and inflexibility as a result of limited availability, access times, required reservation and fixed time limits (the latter only for round-trip and P2P).

In the table seemingly contradicting results are found for the cost component. On one hand it is believed to result in reduced costs (primarily by the general public), while on the other hand carsharing is also experienced to be relatively expensive (primarily by carsharing participants) (SmartAgent, 2011). This can however be explained due to the absence of fixed costs and the presence of relatively high variable costs for shared usage (see also Appendix C): carsharing is thus only up to a certain point cheaper than car ownership.

Looking into the differences between the carsharing types, some more advantages and disadvantages can be found. A disadvantage of B2C carsharing is the presence of vehicle signage. Round-trip carsharing is positively mentioned for their dedicated parking spots, while one-way carsharing is liked for the flexibility. An advantage of P2P carsharing is the social interaction and the large variety of cars one can drive with. An expected disadvantage often mentioned by the general public is that P2P cars may be smudgy or in a bad mechanical state. Moreover, people are afraid of conflicts and facing the owner after causing damage.

In addition to the perceived and experienced pros and cons of carsharing compared to car ownership, the interviewed carsharing organizations are asked for the main motivations of their members to become a carsharing participant (see Appendix A). In general, **comfort** and **costs** are mentioned as the main motives to participate in carsharing. Environment considerations are kept in the back of one's mind, but are not deciding. Additionally, Car2go mentioned that long waiting times for parking permits in Amsterdam also play a role.

TABLE 8: OVERVIEW OF THE EXPERIENCES AND PERCIEVED PROS AND CONS OF CARSHARING COMPARED TO CAR OWNERSHIP

	According to carsharing participants	**According to the general public**
	Advantages compared to car ownership	
Carsharing in general	+ More conscious car usage [A] + Cheaper for occasional usage [A] + Maintenance free [B] + No fixed costs [B] + Good for environment [B] + No need to request a parking permit [B] + Carefree [A, B, D]	+ Maintenance free [A] + No fixed costs [A] + Carefree [D] + More conscious car usage [A] + Reduced costs [A]
B2C carsharing	+ Car always in good state [A] + Possible for last-mile transport in combination with PT [D]	+ Car always in good state [A]
Round-trip carsharing	+ Dedicated parking spot [B]	
One-way carsharing	+ Flexibility to drop car at destination [C]	
P2P carsharing		+ Large variety in car types [D] + Availability (sufficient cars) [D] + Sustainable [D] + Social interaction [D] + Sympathetic [D]
	Disadvantages compared to car ownership	
Carsharing in general	- Not suitable for high yearly mileages [A] - Access time [B] - Limited availability [B] - Relatively expensive [A, B] - Possible problems on arrival [D] - Constant change of car (type) [D]	- Not suitable for high yearly mileages [A] - Limited availability of the (nearest) car [A, D] - Need to make a reservation [A, D] - Need to plan long in advance [A] - Hassle to make a reservation [A] - Access time before getting in the car [A]
B2C carsharing	- Vehicle signage [D] - Possible malfunction of check-out system [D] - Relatively expensive [D] - Membership costs [D]	- Membership costs [D] - Relatively expensive [D]
Round-trip carsharing	- Fixed time-limit [D]	- Fixed time-limit [D] - Need to return the car to fixed parking spot [D]
One-way carsharing		- No certainty, because reservation can only be done last-minute (>30 minutes in advance) [C] - Radius of action electric vehicles [D]
P2P carsharing	- Hassle to make a reservation [A]	- Risk on conflict: Vagueness around insurances, car trouble, fines [D] - Facing the car owner in case of damage [D] - Smudgy cars [D] - Reliability [D] - Availability [D] - Hassle with key-exchange [D] - Uncertainty of state of car [D]

Sources:
A. **(SmartAgent, 2011)**
B. (de Gier, et al., 2014)
C. (Shaheen, et al., 2015)
D. **(ter Berg & Schothorst, 2015)**

2.5.2 Costs comparison between the usage of a shared car and a private car

Knowing that costs are one of the two the most important variables when deciding to become a carsharing participant, it is interesting to know under what conditions carsharing is financially interesting for the consumer.

Figure 9 shows the yearly costs for various mileages for both carsharing and car ownership. The costs for car ownership are based on information of ANWB (2017) and Nibud (2017). For one-way carsharing the costs per time-unit are converted into costs per distance unit, based on an assumed average speed of 30 to 40 km/h. In case of round-trip- and P2P carsharing, costs for tours with various activity times are calculated and converted into costs per kilometre. A detailed explanation on the determination of the costs is attached in Appendix E.

In general, carsharing is found to give the largest financial benefit to people with low annual mileage, because of the absence of (high) fixed costs. However, car ownership is already interesting from around 4000 kilometres per year onwards. The break-even point for round-trip carsharing is estimated to be circa 3,000km; for P2P carsharing it is around 4,000km and one-way carsharing is cheaper up to circa 5,500km. In comparison: a car drives on average 14,200 km per year in The Netherlands (CBS, 2017b).

For the cost calculation of one-way carsharing, it is assumed that the car can always be dropped at destination; parking and waiting costs are thus not taken into account. In reality, one-way carsharing is only available in a very limited number of regions and it is thus very unlikely that the total yearly travel demand is within the boundaries of the one-way working areas.

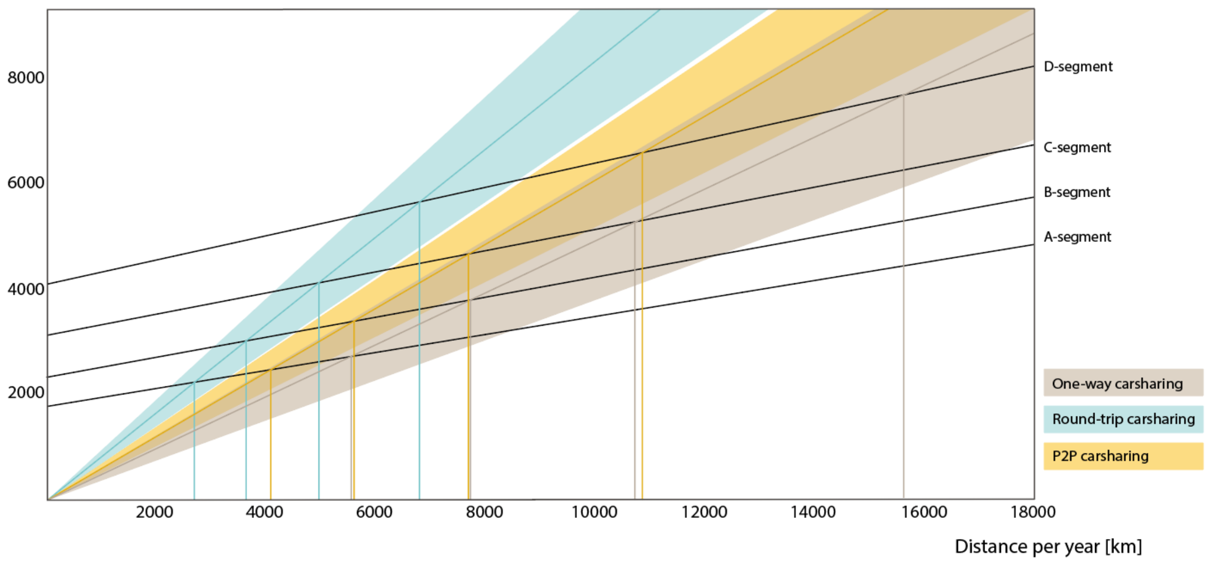


FIGURE 9: CAR OWNERSHIP COSTS VERSUS CARSHARING COSTS BASED ON MILEAGE PER YEAR

2.6 Conclusion

In this chapter it is aimed to gain a better understanding of the carsharing market and to learn what developments can be expected towards the future. Based on the findings in this chapter, the first research question can be answered, and a first provisional answer can be formulated on the second research question. Below, both questions are answered one after the other.

The first research question was formulated as follows: *"What does the current carsharing market in The Netherlands look like and what developments can be expected in the nearby future?".* Below, first the findings on the current state are presented, after which the future expectations are listed.

In this chapter, it is first of all found that **there is no such thing as general carsharing**. Many different types of carsharing exist, each with their own unique features. In this thesis, it is decided to focus on business-to-consumer- (B2C) and peer-to-peer (P2P) carsharing, of which the first can be split into round-trip carsharing and one-way carsharing. In each of the three carsharing types, a clear market leader stands out: At the **SnappCar** platform, 90% of the P2P shared cars can be found; **Greenwheels** accounts for ca. 70% of the round-trip market; and **Car2go** represents almost 80% of the one-way market, although it should be noted that the latter market is subject to fluctuations over the last year. In total, over 20 organizations are active, each specialized in one of the three carsharing types. Only one organizations offers both round-trip- and P2P carsharing: MyWheels.

Second, it is found that **the carsharing market (B2C & P2P) only accounts for a marginal part of the total car travel demand** in The Netherlands. The share of carsharing kilometres as part of all car kilometres driven in The Netherlands, is estimated on 0.03%. Based on an analysis of the supply and demand, it can moreover be concluded **that the supply of shared cars is a poor indicator of the actual usage of a specific carsharing type**. P2P-carsharing offers the largest supply (24,779 cars out of 27,605), while round-trip cars are the most used (25m km out of 43m km driven per year by shared cars).

Moreover, it is concluded **that large variations exist among the carsharing types** in location, service levels, car types and cost structures. The major differences are summarized in Table 9. Differences presented in *italic* script are observed in The Netherlands and might impact the preferences, but are not considered as a logical feature of the specific carsharing type and might thus differ over time.

TABLE 9: MAJOR DIFFERENCES AMONG ONE-WAY-, ROUND-TRIP- AND P2P CARSHARING.

One-way carsharing	Round-trip carsharing	P2P-carsharing
• Available in Amsterdam, Rotterdam, and Groningen	• Available in all cities and larger villages	• Available in all municipalities
• Charges by the minute • Usually does not take a distance unit into account in the cost structure • No booking fee or minimal usage time • Reservation more than 30 minutes in advance not possible • No pre-determined ending time • Varying access time • Flexible drop-off location • *Mainly electric vehicles and thus limited action radius* • *Required usage of mobile application*	• Charges by 15min – 1 hour • Dedicated parking spots • *Requires deposit* • *Accepts both young and unexperienced drivers*	• Charges mostly by day, exceptions apply • Large fleet variety • Usually key exchange needed and thus limited flexibility in start-time of the tour. • Booking time dependent on response time of car owner. • No registration- or membership costs. • Social interaction with car owner

As a result of the variation in cost structures, the carsharing types **vary in trip characteristics**. One-way carsharing is mainly used for short distances, P2P carsharing is often used for trips that take more than a day and round-trip carsharing steers the middle course.

Towards the future, it is expected that **carsharing will grow**, albeit with car ownership retaining its importance. The **largest growth numbers are expected for one-way carsharing**. Moreover, organizations are expected to offer **varying carsharing types at the same time** and a **more varied fleet** with both electric and fuel driven cars. P2P carsharing is expected to become **more anonymous and more flexible** as a result of the **adoption of board computers and carsharing software in private cars**. Last, on the long term, it is expected that **development of automated guided vehicles** will have a severe impact on the carsharing market.

Based on the findings in this chapter, also a first provisional answer, can be formulated on the second research question: *"What are the factors that affect someone's willingness to become a carsharing participant or to purchase a car?"*

It is found that the most important drivers to choose for carsharing participation rather than car ownership are **comfort** (carefree) and **costs**. Environmental concern is kept in the back of one's mind, but is not decisive.

Moreover, poor **parking conditions** (such as parking permit waiting times and difficulties to find an available parking spot) **can** motivate people to participate in carsharing rather than purchase a car. Reasons not to participate in carsharing, are the perceived **uncertainty** and **inflexibility** as a result of access times, limited availability, reservation obstacles and fixed time limits (the latter only for round-trip and P2P). In a cost comparison, it is found that carsharing will lead to **reduced costs up to a yearly mileage of circa 4000km**. An interesting finding in this chapter, is that the **general public is poorly aware of the actual carsharing service leve**l. Non-carsharing participants usually expect shared cars to be in a worse state, less clean, harder to book and less available than perceived by carsharing members. Hence, it is expected that **a better carsharing awareness** will thus also affect someone's willingness to become a carsharing participant.

People who participate in carsharing are found to be **higher educated** and **more environmentally conscious** than the average Dutchmen. Moreover, they earn **higher salaries** and are more often **living in single households** or in **households with children** and also more often **aged below 65**. Last, they are more likely to **live in highly urbanized regions** and **attach less value to car ownership** compared to the average Dutchmen. Among P2P- and B2C carsharing participants, small differences are found: B2C carsharing participants live in more urbanized areas, receive higher incomes, and are higher educated than people participating in P2P carsharing. P2P carsharing participants are more often woman and living in households with children. Apart from demographics, carsharing participants are also found to vary from the general public in terms of mobility behaviour. Carsharing participants **make more trips, use the bike and public transport more often, and make less use of the car**. Moreover, people are found to adapt their mobility behaviour after becoming a participant: mainly other cars and public transport are less often used.

CHAPTER 3

3 LITERATURE REVIEW ON CAR OWNERSHIP- AND CARSHARING PARTICIPATION MODELLING

In this chapter quantitative literature is reviewed towards car ownership- and carsharing participation modelling. The aim of this chapter is twofold: (1) to determine what explaining factors are found in earlier studies and (2) to learn what modelling structures are used in these studies. Knowledge on earlier modelling studies helps to set hypotheses in the conceptual model and provides guidance in the specification of the modelling approach, when operationalization the conceptual model into an empirical model

Because studies to the joint modelling of carsharing participation and car ownership are scarce, this chapter will start with an overview of isolated models towards carsharing participation. Next, a selection of disaggregate car ownership models is reviewed. After that, the limited research is analysed, in which choice models are estimated for the choice between carsharing membership and car ownership. The chapter concludes with an overview of all factors that are found to explain carsharing participation and/or car ownership in earlier modelling studies and presents the major lessons that can be learned from earlier modelling approaches.

3.1 ISOLATED MODELS TOWARDS CARSHARING PARTICIPATION

The modelling studies towards carsharing participation can roughly be split in two types: (1) aggregate models that aim to determine the carsharing adoption rate in an area and (2) disaggregate models that aim to determine whether a certain individual is willing to participate in a carsharing program. Due to this thesis' focus on disaggregate modelling, primarily the latter one is of interest for this study. Disaggregated studies are however scarce, mostly based on SP data, and do not account for P2P carsharing. Therefore, also the aggregated studies are consulted. Below, both types of studies will be discussed one after the other.

3.1.1 AGGREGATED MODELS THAT DETERMINE THE CARSHARING ADOPTION IN AN AREA

A number of studies focus on the estimation of regression models that describe the relation between the carsharing adoption rate in an area and its spatial characteristics. The studies that are looked into are shown in Table 10.

TABLE 10: MODELLING STUDIES TOWARDS CARSHARING ADOPTION IN AN AREA VIA AGGREGATED REGRESSION MODELS

Authors	Dependent variable	Type of carsharing	Study area	Unit of analysis
(Celsor & Millard-Ball, 2007)	Carsharing service (Number of shared cars within half-mile circle)	Round-trip	13 regions in US with 'significant carsharing operations'	Neighbourhood
(Stillwater, et al., 2009)	Average monthly hours of carsharing use	Single operator (round-trip)	Single large metropolitan area in the US	Neighbourhood
(Coll, Vandersmissen, & Thériault, 2014)	Number of carsharing members	Single operator (round-trip)	Quebec City, CA	Neighbourhood
(Hobrink, 2014)	Amount of shared cars	P2P + B2C	Municipalities in NL	Municipality
(Blomme, 2016)	Amount of shared cars	B2C	Cities >150.000 inhabitants in BE, DE, FR, NL and UK.	City
(Münzel et al., 2017)	Amount of shared cars	P2P + B2C	Cities >150.000 inhabitants in BE, DE, FR, NL and UK.	City

As can be seen in Table 10, a distinction can be made in the unit of analysis. Earlier work in Northern-America searches for differences on a neighbourhood level, while more recent work in Europe and The Netherlands is focussed on differences between cities or municipalities. Moreover, the dependent variable varies. In the first and latter three studies the amount of shared cars in the city/municipality is used as a proxy for the carsharing adoption. The validity of this approach is questioned when multiple carsharing types are combined in one model, because the previous chapter showed rather varying ratios of supply and demand among different carsharing types. Therefore, in case of Hobrink and Münzel et al, only the models towards either B2C or P2P carsharing are consulted. The joint models that are also estimated in these studies, are thus not taken into account.

Table 8 shows an overview of the estimation results of each of the studies. A '0' indicates that the relation is tested, but that no significant positive or negative relation was found. Among the results of Hobrink (2014) and Münzel et al. (2017), sometimes a double '++' or '--'sign is shown. This is the case when the effect of a variable is over twice as high for a certain carsharing type compared to the other.

From the estimation results we can learn that large municipalities (in terms of population size) and areas with a relatively high number of middle aged people are expected to have more carsharing participants. Furthermore, a high percentage of single households, highly educated people and commuters by foot raise the carsharing usage level even more, just as the housing density. Opposite that, a relatively high number of car ownership and commuters by car is found to lower the amount of carsharing participants in the area, just as a high percentage of elderly. The mentioned positive and negative relations are all in line with the interviews and the national surveys, of which the results are presented in the previous chapter. Population density is in most studies not found to have a significant effect on the carsharing diffusion, but it should be emphasized that this conclusion might only be valid for large municipalities, since Blomme (2016) and Münzel et al. (2017) only considered cities with a population over 150.000. Besides, a large population often comes hand in hand with a high population density and correlations might thus exist that have influenced the model results.

Table 8 moreover shows some conflicting results on the household income, the percentage of family households, the university presence and the percentage of commuters by public transport.

Apart from the corresponding and conflicting variables, there are many variables that are only taken into account in one or two studies. In some cases, this implies that further research is needed, which is for example true for the impact of policies and the percentage of green party voters. Other variables however are more likely to be a proxy for another variable. The street width and the number of intersections are for example likely to function as proxies for the car accessibility of the area. The car accessibility is also highly influenced by the presence of a historic centre and indirect thus also by the number of housing units before 1940. Therefore, it is expected that car accessibility has a negative relation with carsharing participation: the better the car accessibility, the less carsharing participants. Similarly, the percentage of commuters by foot is expected to indirectly represent the distance to facilities. The distance to facilities on its turn is expected to highly correlate with the housing units per acre.

Some differences among B2C and P2P carsharing can be derived from Table 8. The results of Hobrink (2014) imply that B2C carsharing participants are higher educated, earn higher incomes, live closer to facilities, and are more often living in single households compared to P2P carsharing participants. This is also in line with findings in the previous chapter. Moreover, the study results suggest that B2C carsharing participants are more often non-western households and are more often living in municipalities were policy instruments towards carsharing are applied. These latter findings require additional research, since it is not affirmed by other studies so far. According to the study of Münzel et al. (2017), P2P carsharing participants live in smaller cities where bike sharing organizations or a university is less often present and where green parties are less often voted for. This is in line with findings in the previous chapter, where it was found that B2C shared cars are less often available in smaller municipalities and that B2C carsharing participants are more concentrated around urbanized areas.

TABLE 11: VARIABLES THAT EXPLAIN CARSHARING USAGE ACCORDING TO REGRESSION STUDIES

	(Celsor & Millard-Ball, 2007)	(Stillwater et al., 2009)	(Coll et al., 2014)	(Hobrink, 2014)		(Blomme, 2016)	(Münzel et al., 2017)	
	US	US	CA	NL		BE, DE, FR, NL & UK	BE, DE, FR, NL & UK	
	Round-trip	Round-trip	Round-trip	B2C	P2P	B2C	B2C	P2P
Land-use variables								
City size (population)				+	+	+	++	+
Population density				0	+	0	0	0
Distance to facilities				--	-			
University presence						+	0	-
Historical city						0	0	0
Intersections per acre	+							
Street width		-						
Housing units per acre	+		+					
% units built before 1940	+							
% rental households	+							
Socio-demographic variables								
Young age				-	-	+	0	0
Middle age			+	+	+	+	0	0
High age			-	-	-		0	0
Gender			0					
Higher education	0		+	++	+	+	+	+
Income	+		-	++	+			
Single household	+			++	+			
Families	-		+				0	0
Single parent			+					
Non-Western households				+	0			
Students in higher education						0		
Percentage of Green Party votes						+	+	0
Transportation related variables								
% Commuters by car	-	-					-	-
% Commuters by carpool	-							
% Commuters by PT	+		+			0	-	0
% Commuters by bike	0							
% Commuters by foot	+		+					
% of people shopping by foot			0					
Cars per inhabitant	-	-	-			-		
Bike sharing presence						0	+	0
Presence of B2C carsharing								0
No rail service available		-						
Regional rail service only		-						
Light rail service only		+						
Light- & regional rail		+						
Distance to transit			-					
Carsharing program variables								
Carsharing pod age		+						
Policy related variables								
Presence of a carsharing policy						0		
Allocation or parking lot				++	+			
Allocation of parking licence				+	0			
Financial compensation organization				+	0			
Financial compensation user				-	-			
General information on website				++	+			
Municipality specific information				0	-			
Carsharing campaign				0	0			

In addition to the studies in the table, the work of Becker, Ciari & Axhausen (2017) should be mentioned. In this report a spatial regression model for free-floating car-sharing demand is estimated with only few attributes, where the number of departures functions as the dependent variable. The study shows a positive, but insignificant, effect of public transportation usage and the share of public transport season ticket holders. Another notable result is the significant negative effect of the total number of workplaces.

3.1.2 Disaggregated models towards carsharing program participation

Disaggregated modelling studies on people's willingness to join a carsharing program are scarce. The few available works that will be discussed in this paragraph are shown in Table 12 and an overview of the found explaining variables is presented in Table 13.

TABLE 12: OVERVIEW OF DISAGGREGATED MODELLING STUDIES TOWARDS PARTICIPATION IN CARSHARING AND THE SHARING ECONOMY

Authors	Data	# of records	Carsharing type	Study area
(Zheng, et al., 2009)	SP	3,300	Round-trip carsharing; Monthly Plan (hourly rate) and Annual Plan (includes annual hours)	Residents of the University Community of Wisconsin–Madison, US
(Zhou & Kockelman, 2011)	SP	403	Round-trip carsharing at Austin CarShare; Freedom Plan (regular users) and Limited Plan (infrequent users)	Residents of Austin, Texas, US
(de Luca & Di Pace, 2014)	SP	200	One-way carsharing	Residents commuting between Baronissi & Salerno, IT
(Becker, et al., 2016)	RP	5,814	One-way- and round-trip carsharing	Residents of Basel, CH

As can be seen in Table 12, only four disaggregated studies are looked into. One additional study is found from Korean origin that might be of interest (Kim, Lee, & Choi, 2014), but due to language barriers, this study is not discussed here. The first three studies in Table 3 are stated preference (SP) studies, in which respondents are asked for their willingness to participate in a hypothetical carsharing program. A major disadvantage of SP studies is the potential presence of biases. In SP studies, people tend to give poorly thought out answers and often state a higher willingness to pay (as a result of hypothetical bias) or a higher willingness to change behaviour (optimism bias). The fourth study is the only revealed preference study on a disaggregated level as far as known to the author. In literature, no disaggregate modelling studies were found to P2P carsharing. Below, each of the studies presented in Table 3 is discussed in more detail.

- In the study of Zheng et al. (2009), two logistic regression models are developed to analyse the respondents' willingness to either participate in a monthly or annual plan from a hypothetical organization. The monthly plan consists of a monthly fee and an hourly rate per use. The annual plan includes a number of annual hours for a yearly fixed fee. In the SP study some of the plan characteristics are varied in order to determine its impact on the willingness to participate. In case of the monthly plan, the monthly fee, hourly rate, and distance to the car are varied. For the Annual plan, variation is brought in for the annual fee, the number of annual hours included in the plan, and the distance to the car.
- Zhou and Kockelman (2011) developed two ordered probit models to determine the probability that somebody will join the plans from the organization called Austin CarShare. They asked every respondent on a scale from 1 to 7 how likely they were to join the specific plan. The Freedom Plan has a higher membership fee, but lower usage rates than the Limited Plan.
- The study of De Luca & Di Pace (2014) presents a binomial logit model based on SP data. One of the attributes in the logit model is a satisfaction attribute for the current transport plan. This attribute is the outcome of a prior model, which is estimated based on a large revealed preference dataset.
- Becker, et al. (2016) modelled the carsharing adoption in terms of active membership and frequency of use. Here, only the active membership model is discussed, for the user frequency it is referred to the original

report. Someone is considered an active member with at least one rental in the past last 12 months. The effect of various factors on carsharing membership is modelled via a binomial probit model and estimated on revealed preference (RP) data, as collected via a survey among one-way- and round-trip carsharing members of a single operator in Basel.

Table 13 shows an overview of the estimation results of the studies discussed above. Numerous relations are in line with the earlier findings from the aggregate models: Household density (+), distance to facilities (-), and car ownership (-), PT usage (+), and PT presence (+). Moreover, the table shows that people willing to make a lifestyle change for the environment are more likely to participate in carsharing. A similar relation was already found in the interviews (environmental concern) and the disaggregated models (green party voters). Furthermore, the study of De Luca & Di Pace suggests that the car travel demand (both distance as frequency) has a negative relation with (one-way) carsharing participation. This is in line with the outcomes of the cost comparison, where it was shown that carsharing is less financially attractive for high yearly mileages (see paragraph 2.5.2). Moreover, it is interesting to see that the highest PT quality[10] is negatively related to one-way carsharing. This is however explainable: in the interviews (Appendix A), Car2go stated that the relatively poor public transport connection between west- and east Amsterdam is for their members a motivation to participate. One-way carsharing here thus functions as an alternative for public transport.

At the same time, there are some unexpected outcomes. According to Zhou & Kockelman (2011) education has a negative effect on carsharing participation. This is striking because all other sources consulted, showed an opposite relation (interviews, Dutch market surveys, and (other dis-)aggregated models). No logical explanation could be found for the contradiction and it is therefore assumed that the exception is location- (Texas) and/or organization specific (AutinCarshare). Moreover, it is interesting to see that in the same study a negative relation is found for the income, while one would expect a positive sign based on the user surveys, the interviews and most other model results. It should however be noted that the median household income in the home zone has a positive relation.

New insights that can be gained from Table 13 include the negative correlation of carsharing costs and access time with carsharing participation, which is in line with intuition. Moreover, the table shows that people aware of carsharing, before the start of the SP study, are also more likely to participate in a carsharing program. Furthermore, the study of De Luca & Di Pace implies a negative relation between the satisfaction with the current transport plan and (one-way) carsharing participation. This is considered plausible, since people are creatures of habit and behavioural patterns are hard to change (Aarts, 2009).

Last, for a number of attributes the actual relation cannot be derived. For the impact of students, varying results are found, although it should be emphasized that Zheng et al. (2009) only compared students to other university campus residents (and thus mainly university staff). In the earlier studied aggregated models, the effect of the presence of a University (and thus for students) was also found to vary. Moreover, the impact of employment is unsure. The study of Zhou & Kockelman (2011) implies a negative relation of employment with carsharing participation. However, the applicability of these results on the Dutch population is questionable, because the study also deviating characteristics for income and education. The work of Becker, et al. (2016) also implies a negative relation with employment, but this is contradicting to the user profiles sketched by Greenwheels and Car2go. Therefore, additional research is needed.

Based on the disaggregated models, it is not possible to pinpoint differences among carsharing types with certainty, because attributes vary largely. Based on the few studies, the suspicion is raised that round-trip carsharing is more often preferred by woman, while one-way carsharing is more popular among men (which is affirmed by Car2go in The Netherlands). Moreover, car ownership seems to have a larger negative effect on

[10] Transit service quality zone A requires a maximum departure interval of 5min per main load direction at rail stops within a 500m perimeter, as defined by is defined by Swiss standard SN 640 290.

round-trip carsharing participation than it has on one-way carsharing participation, which implies that round-trip carsharing is more often considered a substitute for car ownership.

TABLE 13: RESULTS OF STATED PREFERENCE STUDIES TOWARDS THE WILLINGNESS TO JOIN A CARSHARING PROGRAM

	(Zheng, et al., 2009)		(Zhou & Kockelman, 2011)		(de Luca & Di Pace, 2014)	(Becker, et al., 2016)	
	Round-trip		Round-trip		One-way	One-way	Round-trip
	Monthly plan	Annual plan	Freedom Plan	Limited Plan			
Land use variables							
Median household income in home zone			+				
Household density in home zone			+				
Employment density in home zone			-	-			
Distance to nearest shopping centre				-			
Household characteristics							
# of adults in household						+	
Household income							+
Individual characteristics							
Aware of carsharing before survey	+	+			+		
Willing to make lifestyle change for environment	+	+					
Age					0	-	
Income			-	-	0	+	
Gender (Male, ref: Female)	-				0	+	
Education			-			+	+
Undergraduate student	+	+					
Foreign exchange student	+	+					
Student			-				
Part-time student				-			
Part-time employment				-			
Living with roommates		+					
Employment						-	-
Occupation: retired							-
Occupation: self-employed							+
Transportation related variables							
Car ownership	-		-	-		-	--
Satisfaction with current transport plan					-		
Weekly travel frequency					-		
Weekly travelled distance					-		
Uses nonprivate vehicle mode for personal errands	+	0					
Uses nonprivate vehicle mode for nongrocery shopping	+						
Respondent usually travels by bus					+		
Transit stops density in home zone			+				
Dummy: highest PT quality in home zone						-	
PT subscription						+	
Round-trip carsharing member						+	
Carsharing program variables							
Costs of carsharing program	-	-					
Walking distance to shared car	-	-	-				

3.2 DISAGGREGATED MODELS TOWARDS CAR OWNERSHIP

Car ownership models exist in many different forms and provide details on many different levels, making them suitable for a wide variety of purposes. For a thorough overview of both aggregated and disaggregated car ownership models in the public domain, it is referred to the work of De Jong, et al. (2004). This paragraph will merely point out the highlights that are interesting in the light of this study. As a result, only model structures and explaining variables of disaggregated car ownership models that aim to determine the number of cars per household, are discussed. Models on an aggregate level (total car fleet in an area) and more detailed models (i.e. lease cars, class, brand, miles travelled per vehicle) are thus not elaborated on.

This paragraph will first highlight some disaggregated model structures, where after explaining variables for car ownership are presented.

3.2.1 CAR OWNERSHIP MODEL STRUCTURES

In the disaggregate modelling of the number of cars per household, various approaches can be distinguished. Figure 10 shows a selection of commonly used approaches that will be discussed below.

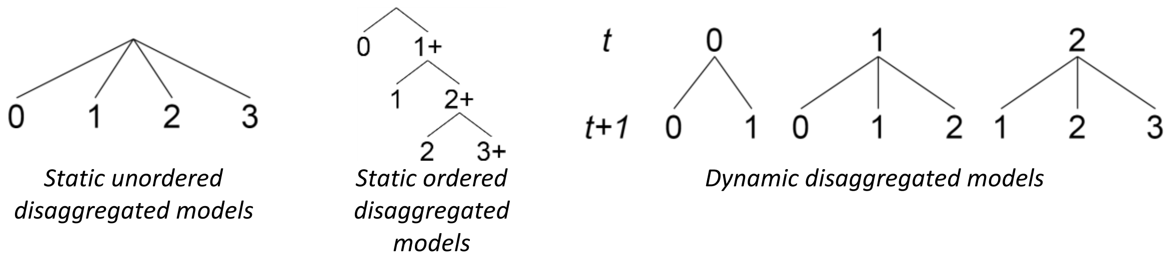


FIGURE 10: SELECTION OF MODELLING APPROACHES FOR CAR OWNERSHIP MODELLING.

In Figure 10, a distinction is made between static and dynamic models. A static model calculates the system in equilibrium and is thus time-invariant. Forecasting with the help of static models is done by adapting the (synthetic) population that forms the input of the model. In contrast, a dynamic model accounts for time-dependent changes. As a result, static models can be estimated based on a single sample, while dynamic models require estimation data over several time steps.

Within the static model approach, both ordered as unordered choice mechanism are often used in practice. An extensive study, in which both choice mechanisms were compared, is conducted by Bhat and Pulugurta (1998). In this study, an ordered–response logit (ORL) model is empirically compared with a multinomial logit model (MNL). The ORL model consists of a series of binary choice decisions, starting at the choice between 0 and 1 or more cars and finishing at the choice between 3 and 4 or more cars. The MNL model consists of 5 alternatives: 0, 1, 2, 3 and 4 or more cars. The comparison was made on several datasets and it was concluded that unordered models more closely represent the true underlying choice process.

The dynamic model approach relies on the assumption that car ownership decisions are made in steps: at a certain time step it is modelled whether the household will scrap a car, keep or replace the current car, or buy an extra car. This type of modelling is also referred to as ‘dynamic transaction models’.

According to the study of De Jong et al. (2014), static models are are *“less suitable for short-run and medium-run predictions, due to the assumptions of an optimal household fleet in every period”.* For those time horizons, it is advised to only predict the changes in the car fleet and for this purpose dynamic transaction models are mentioned as a highly attractive option. For prediction on the long term, dynamic models should be included with a population refreshment procedure. For the long term, also static models can be used, although De Jong et al. point out that cohort effects on the total car ownership might not be well represented.

3.2.2 EXPLAINING VARIABLES IN CAR OWNERSHIP MODELS

Table 14 gives an overview of attributes that are used in various car ownership models in The Netherlands and Flanders. The models are estimated on respectively the Dutch and Flemish transport surveys. Because car ownership models are a widely studied topic and the models are estimated on a relatively large sample, results are considered valid and reliable.

TABLE 14: EXPLAINING VARIABLES IN CAR OWNERSHIP MODELS

	CARMOD (Version GM 3.0)	HHAantal module (DYNAMO 3.0)		Vehicle quantity model (Franckx et al., 2014)	
	NL	NL		Flanders, BE	
		>0 cars (ref 0)	>1 cars (ref 1)	1 car (ref 0)	2 cars (ref 0)
Land-use characteristics					
Population density	-				
Employment density	-				
Rural area	+				
Highly urbanized area	-				
Percentage of agricultural employment of total employment	+				
City size				-	-
Household characteristics					
Number of persons with driving licence	+				
Number of persons without driving licence	+				
Only woman with driving licence	-				
Number of full-time employees	+				
Number of part-time employees	+				
Number of employed people	+	+			
Income	+	+		+	+
Household size		+	+	-	
Single member household				-	--
Head of household characteristics					
Student occupation	-				
Age 35 - 64	+	+	-		
Age 65 - 79	+	+	--		
Age 80+	-	-	--		
Age				+	+
Female head of family				-	-
Education				+	+
Transportation related variables					
Parking tariff in home zone	-				
Car costs			-		
Car travel demand			+		
Share of lease cars			+		
Families who use bus >1/week				-	-
Families who use train >1/week				-	-
Families who use bike >1/week				+	
Distance home address to the place of work				+	+

Table 14 presents the results of three car ownership models. Below each model is briefly described:

- The CARMOD model is an MNL model that distinguishes 4 alternatives: 0, 1, 2 and 3+ cars. The model is estimated by Significance (Willigers, et al., 2017) and based on the MON data of 2007-2009. CARMOD is a submodule of the national travel demand model of The Netherlands.
- DYNAMO is a dynamic automobile market model that determines the total car fleet in The Netherlands and is used by the national government. Within DYNAMO, various modules exist. The results presented here are from the 'HHAantal' module (MuConsult B.V., 2015), which determines the number of cars per household type via an ordered logit model up to 2+ cars. The latest version of the module is estimated in 2015, based on Dutch transport surveys from 2000 to 2009 (OVG & MON).
- The third model of Franckx, Michiels, & Mayeres (2014) is, in contrast to the other studies, not used for national travel demand studies. The study should rather be seen as an explorative study that aims to combine the results of official regional travel survey with a detailed database of vehicle characteristics. In

the study, various sub models are estimated, to determine the car class, the vehicle quantity and the annual mileage per car. The results shown in Table 14 are the outcomes of the vehicle quantity sub model.

Based on the model outcomes as presented in Table 14, is can be concluded that car ownership is more common in rural areas, were population-, employment- and household densities are low. Within the household, both the number of people with a driving licence and the people without a driving licence are found to positively relate to car ownership. Moreover, households with high employment rates and a high household income are more likely to own (numerous) cars, while households with only female drivers are found to own less cars.

Next, some attributes of the head of the household[11] are accounted for. When the head of the household is a student, female, or living in a single household, the car ownership is usually lower. Education and age are found to positively relate to car ownership, although people above 80 are less often in the possession of a car. Furthermore, when the head of the household is aged 65 or older, the chances are much lower that multiple cars are present in the household.

Looking at the transport related variables, it is seen that parking costs negatively affect car ownership, just as car costs. Car travel demand and the distance to work have a positive effect on the total number of owned cars, just as the presence of lease cars (which is modelled in an additional submodule in DYNAMO). Last, it is seen that public transport users less often own a car, in contrast to bike users.

3.3 Studies towards the joint modelling of car ownership and carsharing membership

This paragraph discusses the few studies that jointly model car ownership and carsharing participation. So far, we have seen empirical studies towards carsharing participation or car ownership in isolated models. A major limitation of previous research is that it '*does not sufficiently account for the apparent causal interrelation and joint-ness of carsharing membership with vehicle ownership'* (Mishra, et al., 2015). Instead, the isolated studies towards carsharing participation use car ownership as an endogenous explanatory variable, but this disregards that they are both outcomes of the same choice process. As far as known to the author, there are no car ownership models that use carsharing membership as an endogenous variable.

Joint models towards car ownership and carsharing membership are only recently studied and all date from 2017. Below, first the Dutch work of Kim, et al. (2017a; 2017b) is discussed, where after the work of Becker, Loder, et al. (2017) is elaborated on.

Kim et al. (2017a; 2017b) designed a choice experiment to examine people's intention to join a car-sharing organization. Stated preference data is collected, in which Dutch residents are asked what they would do in a series of hypothetical situations. In the situations, respondents are told to have the possession of one private car and are asked whether they would (1) do nothing, (2) buy a second car, or (3) join a carsharing organization, see also Figure 11. For each alternative the purchase costs, maintenance costs, operating costs, access time and availability of car-use is provided. Moreover, the PT operating costs and access time to the station is given. For the choice study, only respondents were invited that have at least one car and multiple driving licence holders in their household.

[11] The head of the household is the person who contributes most to the household income. If case of equal contribution, either the male, or the oldest one is considered the head of the household.

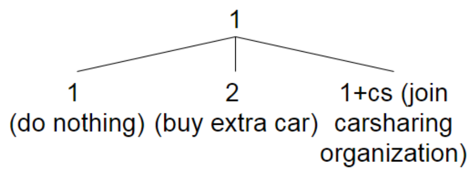


FIGURE 11: CHOICE STRUCTURE IN THE STUDIES OF KIM ET AL. (2017A; 2017B)

In the first study (Kim, et al., 2017b), a discrete choice model that uses random regret minimization is developed. The found relations are presented in Table 15. In the study, the **availability of using a car** is found to be the most elastic attribute in terms of the probability of joining a car-sharing organization and it is therefore concluded that this is the most important service feature of a carsharing organization.

TABLE 15: MAIN FINDINGS OF DISCRETE CHOICE MODEL FROM KIM ET AL. (2017B). REFERENCE: DO NOTHING (STICK TO ONE CAR).

	Buy 2nd car	Join round-trip carsharing organization
Availability of using a car	+	
Socio-demographics		
Gender (male, ref: female)	+	0
Age	--	-
Household size	+	+
Children in household	-	-
Education		+
Satisfaction		
Satisfaction of travelling by car	+	+
Satisfaction of travelling by public transport	-	+
Attributes of 2nd car		
Purchase and maintenance costs 2nd car	-	
Difference in price: 2nd car – current car	-	
Depreciation rate of 2nd car	0	
Attributes of carsharing organization		
Deposit to join carsharing organization		-
Monthly membership fee		-
Hourly rate		-

Among the socio-demographic characteristics, it is interesting to see that gender is only found to have a significant impact for the purchase of a 2nd car, but not for round-trip carsharing participation. Moreover, it is seen that children in the household have a negative impact on both car ownership and carsharing participation, although the household size has a positive influence. This implies that the impact of adults is stronger than the impact of children. For the age and education, similar results are found as in earlier studies. Next, the study shows that satisfaction with the current transport plan, affects the decisions. People that are satisfied with the public transport system are found to be more willing to participate in carsharing, which implies that round-trip carsharing is used complementary to public transport. Last, it is interesting that not only the car costs, but also the difference in price with the current car plays a role in the consideration to buy a second car.

In the second study (Kim, et al., 2017a), the social influence in carsharing decisions is determined. Respondents are asked the same questions as in the previous study, but now they are also asked if they would stick to their choice when one of their friends would make another decision. Here it was found that people tend to be more willing to participate in round-trip carsharing, when friends and family members do so too. The magnitude of the influence varies according to the type of social relationship:

The last study that is discussed here is the work of Becker, Loder, et al. (2017). The study is based on RP data from the Swiss transportation micro census. In this study not only round-trip carsharing participation and car ownership is modelled, but also the possession of a local season ticket and a nation-wide season ticket for public transport. To model the ownership of the four different mobility tools, a multivariate probit approach is used. The study reveals significant correlations in the error terms of the four equations, which indicates that unobserved effects are present. Moreover, the study affirms earlier found relations of public transport accessibility (+), education (+), and age (-) towards carsharing participation. As a result of a relatively low number of observations for carsharing participants, no other significant variables were found. Regarding car ownership, results are also in line with earlier studies. The results show that age and education have a positive relation, just as living in a rural area and being a male. The accessibility of the zone (measure for the distance to employment and facilities) is found to relate negatively to car ownership, just as public transport accessibility.

3.4 CONCLUSION

In this chapter it is aimed to gain a thorough understanding on what factors affect someone's willingness to become a carsharing participant based on earlier modelling studies, and to learn what modelling approaches are used in earlier studies. Below, first the conclusions towards explaining variables are presented, where after the major conclusion on the modelling approaches are presented.

An overview of all explaining variables found in earlier empirical modelling studies, is provided in Table 16. Studies showed no significant impact of population density (although in the same studies a positive relation was found for population size) and the presence of a historic centre.

TABLE 16: EXPLAINING VARIABLES ACCORDING TO EXISTING EMPIRICAL MODELLING STUDIES

	Carsharing participation
Land-use characteristics	
+	Household density
+	Population size
-	Distance to facilities
Household characteristics	
+	Single household composition
Individual characteristics	
+	Education
+	Middle aged
-	Age 65+
Transportation related characteristics	
+	Public transport accessibility
+	Public transport usage
+	Commuters by foot
-	Commuters by car
-	Car accessibility
-	Car ownership
-	Car travel demand
Other	
+	Carsharing awareness
+	Carsharing participants among family and friends
+	Environmental concern
+	Shared car availability
-	Carsharing costs
-	Shared car access time

	Car ownership
Land-use characteristics	
+	Rural areas
-	Distance to facilities
Household characteristics	
+	Household size
+	# of people with driving licence
+	Employment
+	Income
-	# of females
-	Single household composition
Head of household characteristics	
+	Education
+	Age
-	Age 80+
-	Student
-	Female
Transportation related characteristics	
+	Car travel demand
+	Distance to work
-	Parking tariffs
-	Public transport users
Other	
-	Car ownership costs

Apart from the variables listed in the table, a number of relations were found in only few studies or showed varying results and therefore need further testing: **Bike usage** (+ on car ownership), **gender** (+/- on carsharing), **occupation** (in relation to carsharing) and **ethnicity** (in relation to carsharing)

Few differences with the results from the previous chapter should be pointed out. First, the modelling studies were not conclusive on the **income** and the **households with children**. It is however assumed that for the Netherlands a positive relation is at present, because both the interviews as the Dutch surveys showed clear positive relations. Next, for **employment** the modelling results imply a negative relation, while based on the interviews an opposite relation was expected. Here, additional research is thus needed.

Moreover, differences among carsharing types tend to be at present. The studies imply that B2C carsharing participants are **higher educated**, earn **higher incomes** and are more often living in **single households** compared to P2P carsharing participants. Besides, B2C participants live in **larger cities** and **closer to facilities.** Furthermore, the suspicion is raised that **man** more often participating in one-way carsharing than in round-trip carsharing. Last, round-trip carsharing participants seem to be less often in the **possession of a private car** than one-way carsharing participants. All these findings are in line with the interviews and surveys studied in the previous chapter.

Second, the chapter aimed to gain insights in modelling structures used in earlier empirical studies. In the disaggregated model studies, it is found that carsharing participation is modelled on an individual level, while for car ownership usually the household level is used. Among the disaggregated carsharing models, little variation in model structure was found: the models are all static and either binary logit or probit models. In contrast, car ownership models vary largely. Based on the studies consulted in this chapter, it can be concluded that unordered models more closely represent the true underlying choice process than ordered models. Furthermore, literature showed both dynamic as static models. For the estimation of a dynamic model, larger data sets are required, but they tend to give better results for short- to mid-term predictions. For long-term predictions, static models could be used, although cohort effects are not well represented in these models.

CHAPTER 4

4 CONCEPTUAL MODEL FOR CAR OWNERSHIP AND CARSHARING PARTICIPATION

The previous chapters showed many variables that relate to carsharing participation and car ownership, but the literature study did not show to what extent internal relations exist between the variables and thus whether these variables are directly or indirectly related to carsharing and car ownership. To gain a better understanding of the internal relations, in this chapter a conceptual model for car ownership and carsharing participation is constructed. The conceptual model guides the development of an empirical model and furthermore provides guidance in the interpretation of empirical modelling results (Pace, 2002).

A conceptual model is a visualized representation of systems dynamics and consists of variables and their internal relations. The variables represent characteristics of system elements. A conceptual model is not yet empirically specified and is thus only a hypothesis of the system's dynamics.

In order to set up the conceptual model, first the system boundaries are considered. In the introduction, the scope of the study was set to car ownership and carsharing participation in general. During the literature study it was however found that various forms of carsharing exist and the question rises whether all types of carsharing are interesting to model and should thus be part of the system. Next, the system elements are determined: on what level is car ownership and carsharing participation decided? Having set the system boundaries and the system elements, the conceptual model can be created.

4.1 SYSTEM BOUNDARIES

The literature study showed that there is no such thing as general carsharing participation. Motivations to participate in round-trip carsharing differ substantially from one-way carsharing and people participating in round-trip carsharing are not necessarily willing to participate in P2P carsharing. On top of that, it is found that pricing schemes and flexibility differ largely. In the modelling of carsharing participation, a distinction should thus be made between different carsharing types.

In this study, the scope of the research is further narrowed to the modelling of car ownership and round-trip carsharing participation. P2P carsharing and one-way carsharing are thus excluded. Below, both exclusions are substantiated one after the other.

4.1.1 EXCLUSION OF P2P CARSHARING

Towards the future, P2P carsharing is expected to become more similar to round-trip carsharing and the choice between the two types will thus become less explicit. This expectation is based on P2P carsharing market developments on the one hand and a comparison with the P2P housing market on the other hand:

- **P2P carsharing developments**
  An important development is the appearance of board computers that enable people to open private cars with their mobile phones. Key-exchange is thus no longer needed, which is likely to reduce the access time and the minimal rental time. In this way, P2P carsharing will not only become more accessible, but also more anonymous and the reluctance of B2C users towards P2P-carsharing is thus likely to decrease. An uncertainty is the cost development. P2P-carsharing is usually cheaper, but tax authorities are currently struggling with the regulations for the sharing economy (NOS, 2016). In the long run, it is not inconceivable that people have to pay taxes over the income out of P2P-carsharing rentals and prices might thus rise.
- **Comparison with P2P housing market**
  In the P2P housing market, it is seen that the boundaries between B2C and P2P rental have already faded. Airbnb, world's largest P2P sharing platform, once started as a platform where individuals offered an

available room at their home for strangers, often looking for some social interaction, but has grown into a platform where an increasing number of people see economic chances to rent their complete house for high amounts (Oskam, 2017). Providers are becoming more professionally organized and often own multiple housings, which they rent out via Airbnb. The reduced gap between the service of Airbnb and travel organizations, resulted in a larger group of people willing to use Airbnb as an alternative for a regular hotel. It should be noted that an increasing number of governmental organizations are designing regulations to limit the professionalizing of P2P sharing. The Dutch state for example obliges people to pay taxes over the income they get via Airbnb, although in practice this is barely done (RTL Z, 2015). Furthermore, various cities levy tourist tax on Airbnb rentals (NU.nl, 2014; Mulders, 2017) and some even constrain the maximum number of nights that a private home can be rented out (Kraniotis, 2016).

The expected developments in the P2P carsharing market imply that in the future P2P- and round-trip carsharing participation could be modelled as a single membership choice. The relevance of modelling P2P carsharing is further doubted because P2P carsharing is often used for holiday related trips, which suggests that not all kilometres are driven within the country and are thus outside the scope of national strategic travel demand models. Last, P2P carsharing members are rather limited shared car users compared to round-trip and one-way members (de Gier, et al., 2014): P2P carsharing is used a few times per year, while B2C carsharing is rather used a few times per month on average. Therefore, this study will no longer take into account P2P carsharing.

4.1.2 Exclusion of one-way carsharing

The decision not to include one-way carsharing participation originates from the assumption that this type of carsharing should not be modelled jointly with car ownership. During the literature study it was found that primarily round-trip carsharing and to a lesser extent also P2P carsharing are considered as an alternative for car ownership, potentially supplemented with one-way carsharing. One-way carsharing on its own is not a suitable alternative for car ownership, because of its limited working area and limited radius of action. Case studies have also shown that one-way carsharing is on average more often used as a substitute for local public transport and bike transport than for private car usage (Schreier, Becker, & Heller, 2015; Martin & Shaheen, 2016). It is therefore assumed that one-way carsharing is rather an additional choice that depends among others on the number of cars in the household and participation in other types of carsharing.

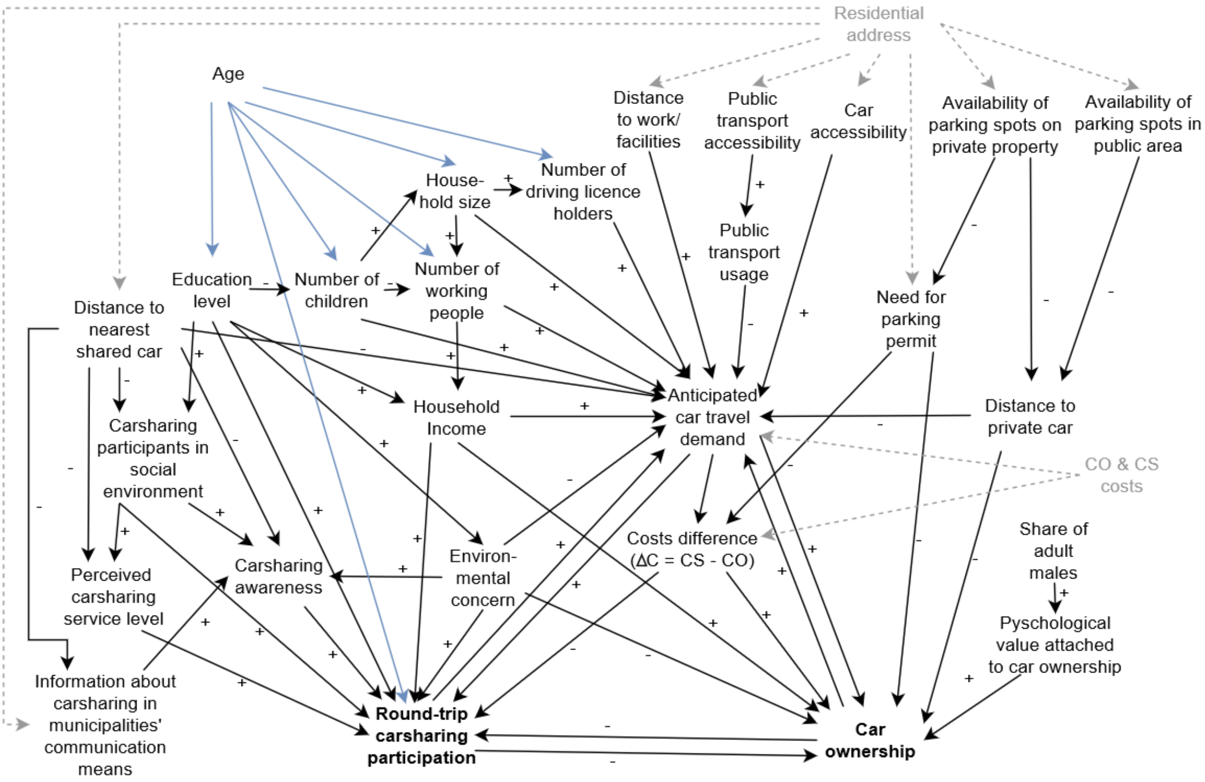
4.2 System elements

The appropriate decision unit for car ownership and carsharing participation is found to be the household level. Scientific literature showed that disaggregated models on a household level have become the preferred approach to model car ownership (Bhat & Pulugurta, 1998). This makes sense, because the purchase of a car has consequences for the household budget and the decision for the number of cars is thus likely to be made by mutual agreement. Moreover, cars are often shared with other household members.

The decision unit for carsharing participation is more complicated. In the overview of the various carsharing organizations, it is found that only Greenwheels offers memberships on household level, while all other organizations allow a maximum of one driver per membership. However, a private carsharing membership impacts other household members in various ways and therefore the household is considered as the appropriate decision unit. A carsharing membership for example impacts the household budget and the car availability of other cars in the household. Moreover, carsharing participation of one household member enables others to drive along as a passenger. Modelling carsharing participation on a household level contrasts with earlier disaggregated carsharing participation models. It is however assumed that in earlier studies this choice is not specifically made. Most studies are based on SP data (Zheng, et al., 2009; Zhou & Kockelman, 2011; de Luca & Di Pace, 2014), which is hard to collect on a household level. The only exception is a study based on the national Swiss travel survey, in which the decision unit was determined by the available data (Becker, et al., 2016).

4.3 CONCEPTUAL MODEL FOR ROUND-TRIP CARSHARING PARTICIPATION AND CAR OWNERSHIP

The conceptual model for round-trip carsharing participation and car ownership is shown in Figure 12. The conceptual model consists of variables and arrows that represent the endogenous links between the variables. The variables can vary over time and represent characteristics of the system elements. The system elements in this case are the households. The arrows between the variables are provided with a plus or minus sign that represents the impact of a growth of the variable at the source of the arrow on the variable at the end of the arrow.



** Lines in blue indicate that there is a relation between the variables, but one that is not constantly positive or negative. Those relations are discussed in the text. Dotted lines represent the context of the system.*

FIGURE 12: CONCEPTUAL MODEL OF CAR OWNERSHIP AND CARSHARING MEMBERSHIP.

The variables shown in the conceptual model are based on the factors that are found to relate to either carsharing participation or car ownership during the interviews and the literature study. The variables are critically judged in order to place them in the right hypothesized position in the conceptual model: Does the variable indeed explain carsharing membership or is it rather reluctance to car ownership? Is the variable expected to directly affect carsharing or does it rather have an indirect impact via other variables? Furthermore, extra variables are added, because they are expected to impact the variables that are deduced from literature study. The hypothesized internal relations between variables, as shown in the conceptual model, are based on national statistics, insights gained during the literature study and additional literature. Below, the variables and internal relations are discussed in more detail.

The anticipated car travel demand is assumed to play a major role in the decision for carsharing and/or car ownership. The higher the car travel demand, the higher the need for car ownership and/or carsharing membership. Interviews and market surveys have shown that the choice between car ownership and carsharing largely depend on the usage costs. The usage costs for carsharing and car ownership are built up in a different way and as a result, carsharing is only up to a certain car travel demand cheaper than car ownership. Car travel demand should here be considered as the combination of yearly mileage and 'car usage time', because costs for round-trip carsharing are both affected by mileage and time.

In the literature study many variables showed up that relate to car ownership and carsharing membership, which are actually assumed to explain the car travel demand. Examples are the household size, the environmental concern, the number of employees, the public transport accessibility, and distance to work and other facilities. Furthermore, people with a higher income are found to travel further (CBS, 2017d) and it is expected that they are more likely to travel by car, since their value of time is higher.

The car travel demand is however not only a cause of car ownership and/or carsharing membership, but also a result of it. Literature showed that car ownership affects the car travel demand (de Jong, et al., 2004): when the fixed costs are already paid for anyhow, additional kilometres are relatively cheap and the costs thus only form a low obstacle for trips that were before made with other transport modes. The relation of round-trip carsharing participation on car travel demand is less clear. Research has shown that the car travel demand on average lowers as a result of round-trip carsharing participation (Nijland, van Meerkerk, & Hoen, 2015). This decrease is primarily caused by households who disposed of their privately owned and changed it for a shared car. The decrease is a logical effect of the increased threshold to use a car, as a result of higher variable costs per kilometre, the need to reserve a car in advance and the increased access time. For other households, it can be assumed that the round-trip carsharing participation increases the travel demand, because it enables households to make tours that could not be made easily elsewise.

Apart from the car travel demand, the literature study showed a number of other variables that relate to car ownership and/or carsharing membership. Below, for each of the variables it is discussed whether the impact is direct or indirect.

First, the awareness of carsharing is expected to have a direct effect on carsharing participation, just as the perceived carsharing service level. Currently carsharing, and in particular the reservation system, is by non-carsharing participants often perceived as a hassle and people are therefore reluctant to participate in carsharing (SmartAgent, 2011). At the same time, carsharing participants speak highly of the ease of reservation. It can thus be stated that people are reluctant to carsharing out of ignorance of the real service level. An increased awareness of carsharing and the actual service level is thus assumed to lead to more carsharing participants. The carsharing awareness and perceived service level on their turn are assumed to relate closely to the actual presence of shared cars in the neighbourhood (and thus the distance to the nearest shared car), the information provided by the municipality, and the presence of carsharing participants in the social environment, of which the latter also has a direct effect (Kim, et al., 2017a).

Next, the environmental concern is expected to affect the decision in various ways. First of all, a high environmental concern is assumed to result in reluctance to car ownership and car transport in general. Second, households with a high environmental concern are assumed to be better aware of carsharing, because they search more actively for more sustainable transport alternatives. Third, it is assumed that environmental concern also has a direct effect, because the shared car is presented as a sustainable transport mode compared to the private car. This is because carsharing offers the possibility to adapt the car size (and thus the pollution level) to the travel purpose. Besides, the fact that shared cars are more intensively used, results in a faster replaced (and thus more fuel efficient) fleet and prevents cars to depreciate without being used.

Furthermore, the psychological value attached to car ownership is found to play a role. In the literature study it was also found that car ownership is more popular among men, but this is expected to be largely correlated with the psychological value attached to car ownership: man are assumed to derive more status from a car than women do.

Moreover, the education level is found to relate to both car ownership and carsharing membership, although it is assumed that this is mainly an indirect effect. Statistics show that people with a higher education level are receiving higher incomes (CBS, 2017a) and research has shown that highly educated people also have a higher environmental concern (Economic and Social Research Council, 2011; Schyns, 2016). Furthermore, social research has shown that the higher educated people are, the larger their social network (Fischer, 1982, pp. 251-255), which makes them more likely to have carsharing participants in their social environment. Besides, it is assumed that someone's social environment consist largely of people of the same education level. The fact that carsharing participants are more often highly educated, might thus further increase the chances for highly educated people to have carsharing participants in their social environment.

Likewise, the age of the household members is also a variable that is expected to have mainly indirect effects on the system. Statistics show that young adults and elderly are for example living in smaller households (CBS, 2016). Furthermore, age is related to education: in former days, a high education was less accessible and therefore less common, especially for women (CBS, 2007). Likewise, driving licence possession differs over the age categories (CBS, 2018). Last but not least, age is a decisive factor for retirement.

In addition, the suspicion is raised that there is also a direct effect of age and education towards carsharing participation. Carsharing is a new and developing service and the users are thus mainly early adopters. According to Rogers (1996), early adopters are on average younger, have a higher financial liquidity, and are higher educated than late adopters.

Last, the access time to the private- or shared car is expected to play a role. A higher access time in general will reduce the car travel demand. Moreover, the relative difference in access time is assumed to influence the choice between carsharing and car ownership. Round-trip shared cars have a dedicated parking spot and the access time is thus constant, as long as the supply and availability do not change. Because the availability is an uncertainty, it is expected that the number of shared cars within acceptable access time also plays a role in the decision to become a carsharing participant. The access time to the private car depends on the parking location and thus on the availability of parking spots in the public area and on private property. For parking in the public area, furthermore parking permits may be required, of which the waiting time and costs increase when the available parking spots in the area are low. Besides, the number of parking permits might be restricted, which can result in a largely increased access time for the second or third car.

As can be seen in the conceptual model, the residential address is indirectly affecting the choice behaviour: it does not only affect the car travel demand, but also determines the parking availability and the presence of shared cars. During this study, the land-use variables are considered as mere exogenous variables and are thus assumed not to be affected by other variables in the system. It is however acknowledged that this approach is questionable: the choice where to live is likely to be affected by mobility preferences (Pinjari, et al., 2008; van Wee, 2009), although Dutch research has shown that only travel time to work and to the previous dwelling affect the housing choice; the accessibility to services and public transport was not found to have a significant effect (Blijie & de Vries, 2006). Moreover, correlation might be at presence, because certain household characteristics might affect both the housing choice and the car ownership choice (such as household composition and income).

4.4 Conclusion

The aim of this chapter was to construct a conceptual model, of which the result is shown in Figure 12. In the conceptual model only round-trip carsharing is represented, because it is concluded that (1) P2P carsharing will become more similar to round-trip carsharing and (2) one-way carsharing should not be modelled jointly with car ownership, but as an additional choice that depends on car ownership and participation in other types of carsharing. The appropriate decision unit for the conceptual model, was found to be the household level.

The question to which extent the conceptual model is a valid representation of the reality, can only be answered by empirical analysis. In the next chapter, the conceptual model will therefore be operationalized into an empirical model.

CHAPTER 5

5 EMPIRICAL MODEL FOR CAR OWNERSHIP AND ROUND-TRIP CARSHARING PARTICIPATION

The aim of this chapter is to determine to what extent the conceptual model is a valid representation of the reality. To do so, the conceptual model is operationalized into an empirical model. An empirical model is a quantified model that is based on statistical data analysis. In this study, existing data is used that is collected by TNS NIPO on behalf of the KiM (de Gier, et al., 2014).

The usage of existing data brings in certain limitations for the empirical modelling specification and therefore first the available data is explored and cleaned from untrustworthy records. In the second paragraph the model structure is specified, which includes the specification of the alternatives and the modelling approach. The third paragraph encloses the empirical model estimations. Next, conclusion are presented on the extent to which the conceptual model could be operationalized into an empirical model and whether the conceptual model was found to be a good representation of the reality. The chapter concludes with an evaluation of the empirical model and recommendations for future research.

5.1 EXPLORATION OF THE PROVIDED DATA

The carsharing monitor, as conducted by TNS NIPO, is set up with the aim of gaining a better understanding of the (potential) carsharing user in The Netherlands (de Gier, et al., 2014). The aim of this paragraph is to determine to what extent this dataset can be used for a different purpose: the estimation of a car ownership and carsharing participation model.

This paragraph will first describe the data collection process of TNS NIPO. Next, it is explored to what extent car ownership and round-trip carsharing participation can be deduced from the sample data. After that, the eventual presence of the hypothesized influencing characteristics (as presented in the conceptual model) is determined. If the characteristics are not present in the sample data, it is explored to which extent the sample data can be enriched with external data sources. Moreover, this paragraph discusses the clearance of untrusted records and concludes with descriptive statistics of the sample data.

5.1.1 DATA COLLECTION OF TNS NIPO

In order to gain insight in carsharing usage, TNS NIPO set up a survey in three rounds. The questions asked in every round, are collected in Appendix F.

- **First round (75,069 observations out of sample of 75,235) –** 6-24 April 2014.
  The first round consists of a screening of the TNS NIPO panel, which meets the golden standard[12]. Only people were approached aged 18 years and over and in the possession of a driving licence. TNS NIPO asked them if somebody in the household once participated in carsharing (either P2P or B2C and either usage or rental). Based on the results of this first round, the total carsharing participation in The Netherlands is estimated and a panel selection is made for round 2.
- **Second round (1,835 observations) –** 22 May - 7 July 2014
  In the second round an online questionnaire towards carsharing awareness, participation motivations, and usage frequency is sent out to a selection of the panel. In the panel selection, carsharing participants (either P2P or B2C and either usage or rental) are over-represented. It is important to mention that if there was a carsharing participant in the household, that person is the one who filled in the questionnaire. Carsharing

[12] The golden standard is a calibration instrument for national and regional samples and set up by MOA and CBS. A sample that meets the golden standard is a sample that is representative for the Dutch population based on sociodemographic characteristics.

usage is thus known on household level: when a respondent is not a shared car user, there is no one else in the household who is.

- **Third round (505 observations) –** 27 November – 23 December 2014
  An additional survey is sent out to carsharing participants only, which is more focussed on car types and changing mobility behaviour. Some respondents from the second round are questioned again (236 respondents) and some new people (269 respondents) are approached.

During this study, only the information as collected in round 2 is used for estimation purposes. This is first of all because only part of the questions is asked in both the second and the third round. Second, many inconsistencies were found between round 2 and round 3, which can to a large extent be explained by differences in phrasings of the questions. Third, it is unclear whether the sociodemographic panel data is updated in between round 2 and 3. In a mail conversation, De Gier (one of the researchers that conducted the survey) expressed the suspicion that this did not happen.

Regarding the data collection in round 2, there are some important remarks to make. First, one would expect the sample to be representative for the complete population, because the respondents were (apart from the oversampling of carsharing participants) randomly selected from the panel that meets the golden standard. It is however found that around 20% of the respondents are living in Amsterdam and this oversampling shows both in the carsharing- as in the non-carsharing group.

Next, from all respondents in round 2, it is unknown whether they stated to be a carsharing participant in the first round. It is thus unknown whether a certain respondent should be classified in the over- or under sampled group. During this study, it is assumed that all people who stated to have participated in either P2P or B2C carsharing in round 2, also stated to be a car sharing participant in the screening round.

A final remark should be made on the demographic field 'Municipality'. This information was initially not available in the data, but is added on request in December 2017. TNS NIPO however does not store old information and could only provide information on the current municipality, while the survey was conducted in 2014. When the respondent has moved in the meantime, the municipality information is thus incorrect. To account for incorrect municipality information, the urbanization degree and the province of the respondents as known in 2014 are compared with the municipality in 2017. Based on this comparison, it was found that at least 160 respondents have moved in the meantime.

5.1.2 CAR OWNERSHIP AND ROUND-TRIP CARSHARING PARTICIPATION IN THE TNS NIPO SAMPLE

To be able to estimate an empirical model, one should know the number of cars in the household and the presence of a round-trip carsharing membership for every household in the sample. The number of cars is collected up to three or more cars. Round-trip carsharing membership is however more complicated to distract from the data and cannot always be determined with certainty. This paragraph describes the assumptions that are made.

To determine whether or not somebody is participating in round-trip carsharing, a number of questions are consulted, see also Table 17. Somebody who is participating in round-trip carsharing membership is expected: (1) to tick the first box in Q16, (2) to indicate in Q19 to use a shared car via an organization like Greenwheels at least once a year and (3) to rent a car at Greenwheels, MyWheels, ConnectCar or another organization that is not listed Q24.

It was found that some of the participants gave inconsistent answers. People who stated not to rent a car via an organization in Q16, sometimes stated to use a shared car of a carsharing organization at least once a year in Q19 and vice versa. It is assumed that this is an effect of the poorly asked question in Q16 and therefore the answer on Q19 is leading in the determination of carsharing participation of a household. Question Q16 is long and there are actually two questions asked in once. A fast reader might check the box that reads 'Yes', when he is only planning to do carsharing in the next 12 months. Furthermore, question Q16 is not explicit in the type of organization, therefore people participating in classic car rental, business carsharing, P2P carsharing and/or B2C carsharing, might all answer 'Yes' to this question. Besides, there might be people who use a Greenwheels car, but state 'No', because they interpret the question as a question towards classic car rental.

Based on the answer on Q19, one can determine whether a respondent is participating in B2C carsharing. To make the distinction between one-way and round-trip carsharing, question Q24 is consulted. If people indicated to participate in B2C carsharing in Q19 and stated to rent their shared car at Greenwheels, MyWheels or ConnectCar, they are classified as round-trip carsharing participants. In the case 'Other' is ticked, it is also assumed the respondent is a round-trip carsharing participant, because there were no other one-way organizations apart from Car2go at the time the survey was held. All other organizations in the list are P2P-, one-way-, or business carsharing organizations. Greenwheels also offers business carsharing, but this is only a fraction of their business and therefore ignored in this study.

A difficulty comes in for all respondents who stated not to have rent a car in Q16, but did state to have used a B2C shared car in Q19, because these people are not asked for the organization at which they rented a car (Q24). In this case, answers to similar questions in round 3 are consulted when available and in all other cases the municipality is consulted. It is assumed that all respondents living outside the capital are participating in round-trip carsharing, because one-way carsharing was only available in Amsterdam at the time the survey was held. For 16 respondents living in Amsterdam, it could not be determined whether they are using one-way or round-trip carsharing.

TABLE 17: QUESTIONS TOWARDS CARSHARING PARTICIPATION IN ROUND 2. THE QUESTIONS ARE FREELY TRANSLATED TO ENGLISH, THE ORIGINAL DUTCH VERSION CAN BE FOUND IN APPENDIX G.

	Questions towards carsharing participation
Q16	Have you rent a car from an organization in the past 12 months? Or are you planning to do so in the coming 12 months? ☐ Yes, I have rented a car via an organization in the past 12 months; ☐ No, I have not rented a car via an organization in the past 12 months, but I am planning to do so in the coming 12 months; ☐ No, I have not rented a car via an organization in the past 12 months, and I am not planning to do so either in the coming 12 months.
Q19	Could you indicate how often you travel with which travel modes in the schedule below?

	Never	1-2 days per year	...
A rental car (i.e. via Hertz)	☐	☐	☐
A car that you rent via a carsharing organization like Greenwheels	☐	☐	☐
A car that you rent from an individual, but via an intermediate organization (like SnappCar)	☐	☐	☐
A pool car that is made available by the employer	☐	☐	☐
...	☐	☐	☐

Q24	At which of the organizations listed below have you rented a shared car? (multiple answers possible) *(only asked if indicated 'Yes' in Q16)		
	☐ SnappCar	☐ MyWheels	☐ WeGo
	☐ Mobilitymix	☐ ConnectCar	☐ Other
	☐ Greenwheels	☐ Car2go	☐ None

5.1.3 PRESENCE OF HYPOTHESIZED INFLUENCING CHARACTERISTICS IN SAMPLE DATA AND EXTERNAL DATA SOURCES

In the conceptual model various household-, land-use- and other transport related variables are distinguished that are hypothesized to have an effect on either car ownership and/or carsharing membership. In order to empirically test these hypotheses, it is required that information on these characteristics is available in the sample data. In Table 18 for each characteristic it is indicated whether information is present in the sample data and if not, comments are given on the extent to which proxies are available or could be derived from external data sources. Below, first the characteristics of which information or proxies are available in the TNS NIPO sample are discussed, after which the external proxies are further elaborated on. The possible data collection of the remaining characteristics is discussed in the recommendations.

TABLE 18: PRESENCE OF HYPOTHESIZED INFLUENCING CHARACTERISTICS IN SAMPLE DATA AND EXTERNAL DATA SOURCES

Hypothesized influencing characteristic	Present in TNS NIPO sample	Comments
Land-use variables		
Distance to work/facilities	Proxy	**Proxy:** urbanization degree on municipality level
Availability of parking spots in public area	External proxy	Average price for short stay parking in the municipality
Distance to available parking spot		
Need for parking permit		
Car accessibility	External proxy	Accessibility indicator for car transport on municipality level (BBI)
Public transport accessibility	External proxy	Accessibility indicator for public transport on municipality level (BBI-ov)
Distance to nearest shared car	External proxy	Average density of shared cars in municipality
Number of shared cars within walking distance	External proxy	Total number of shared cars within municipality
Household characteristics		
Household size	+	Only up to 6 persons
Education level	Proxy	**Proxy:** Education level of respondent
Number of children	Proxy	**Proxy:** Household composition. Single household; adult household with multiple persons or household with children
Number of working people in household	-	
Household income	+	Gross household income
Number of adult males in household	-	
Age (on household level)	+/-	Three measurements available: (1) Age partner of breadwinner in 5 classes in adult households; (2) Age of youngest child in 2 classes in households with children; (3) Age respondent
Number of driving licence holders	-	Only known that there is at least 1 driving licence holder
Other		
Car travel demand	-	
Yearly cost difference between car ownership and carsharing participation	-	Can be calculated when car travel demand (in terms of distance and time) is known.
Availability of parking spots on private property	-	
Shared car availability	-	
Psychological value attached to car ownership	-	
Awareness of carsharing	Proxy	**Proxy:** Carsharing awareness of the respondent
Number of round-trip carsharing participants in social environment	Proxy	**Proxy**: Presence of carsharing participants in social environment of respondent
Perceived carsharing service level	-	
Environmental concern	External proxy	Percentage of green votes in municipality. Based on election of 2012
Information about carsharing in municipalities' communication means	External proxy	Information available on municipality's website

INFORMATION PRESENT IN TNS NIPO SAMPLE

From the list with land-use variables, none of the variables is asked for is asked for in the TNS NIPO sample. However, a proxy can be used for the distance to work and facilities: the urbanization degree of the municipality. The urbanization degree represents the household density. It is assumed that a higher household density comes along with more facilities and more job opportunities. A similar approach is used in earlier modelling studies (Celsor & Millard-Ball, 2007; Coll, Vandersmissen, & Thériault, 2014).

Regarding the household characteristics, only two variables can be distracted directly from the sample: household size and household income. In the case education level, individual responses are used as a proxy. Moreover, the sample data contains information on the household composition, which stores information on the presence of children, which is used as a proxy for the number of children in the household. Furthermore, age information is available, although no measurement is available on household level for all records. The sample data includes the age of the respondent, the age category of the partner of the breadwinner in case of adult households, and the age category of the youngest child in households with children. When no partner is present in the adult household (single households or no partner relation), the age of the breadwinner determines the age category.
From the other variables listed in Table 18, the carsharing awareness, and the presence of carsharing participants in the social environment can be derived from the sample data, albeit on an individual level.

DATA ENRICHMENT WITH EXTERNAL DATA SOURCES

Because only a selection of the characteristics is present in the sample data, external data sources are collected and linked based on the municipality the respondent is living in. As already stated in paragraph 5.1.1, the municipality is unknown for 160 records and in these cases, no data enrichment is performed.

To account for land-use variables, mostly external data sources are consulted. The parking tariffs are derived from the input data of the transport models of Rijkswaterstaat and are collected by ABF Research in 2014 (Groenemeijer, 2016). NRM zones are subzones of municipalities. To convert the parking tariffs of the NRM zones into parking prices per municipality, weighted averages are determined based on the number of inhabitants per zone.

To quantify the accessibility of a municipality, the existing accessibility indicators (BBI's[13]) for public transport and car transport are used. The accessibility indicator for public transport represents how well a municipality can be reached from other municipalities based on the average travel time per kilometre, and is derived from a study at Significance (de Bok & Wesseling, 2017) commissioned by the KiM (2017). Significance presented various alternatives and for this study the indicator is selected that is weighted to the total travel demand. The indicator for car transport that was earlier published in the SVIR[14] (Ministerie van Infrastructuur en Milieu, 2012), is a similar measurement: here the average travel time per distance unit to reach the municipality by car determines the indicator. In contrast to the public transport indicator, in this case only the car travel demand towards the municipality is used and thus not the total travel demand. Both indicators are based on the network of 2014, which is in line with the time period the TNS NIPO survey was conducted.

Information on the supply of shared cars is provided by CROW/KpVV and originates from their count in March 2014. The information includes data on the number of round-trip cars per municipality and is put together based on information received from the carsharing organizations. The data is not publicly available, but permission is received to use the data for estimation purposes. In combination with the surface area of the municipalities in 2014 (CBS, 2017e), furthermore an average density of round-trip shared cars per municipality is determined.

For the environmental concern of a household, a proxy in the form of the percentage of "green voters" in the municipality is used. This variable describes the percentage of people voting for the top three green parties according to Veltkamp (2012) in the Second Chamber elections in 2012 (Kiesraad, 2012). A similar variable is used in earlier studies and found to have an explanatory character towards carsharing (Münzel, et al., 2017)

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[13] BBI: Bereikbaarheids indicator [Accessibility indicator]
[14] SVIR: Structuurvisie Infrastructuur en Ruimte (Structural Vision Infrastructure and Environment)

The last external proxy is a dummy variable for the presence of carsharing information on the municipality's website. The information is collected in 2014, as part of a quantitative study towards the regional differences in the adoption of carsharing in The Netherlands (Hobrink, 2014).

5.1.4 DATA CLEARANCE

During the analysis of the provided data, it was found that part of the respondents gave inconsistent or implausible answers. Multi-interpretable questions account for part of the inconsistencies, in other cases it can only be concluded that the answers are unreliable. As a result, all answers on Q3 are eliminated, in which the most used mode for various travel purposes is asked for. Furthermore, the records of 48 respondents are eliminated, because they either gave inconsistent answers on clearly asked questions, because the suspicion is raised that answers were filled in at random or because they did not complete the whole survey. It is assumed that the inconsistencies are randomly distributed over the sample. Apart from the oversampling of carsharing members, the sample is thus still assumed to be representative for the complete population.

5.1.5 DESCRIPTIVE STATISTICS OF THE SAMPLE DATA

Table 19 and Table 20 show the sample distribution after the elimination of untrustworthy records. The complete sample consists of 1787 records, among which 262 households participating in P2P and/or B2C carsharing. The carsharing participants are oversampled and actually represent 1.9% of the complete population. Among the oversampled carsharing participants, a distinction is made in households who participate in round-trip carsharing and households who participate only in other forms of carsharing. The distinction in the different groups is based on the responses in the survey and certain assumptions as discussed in paragraph 5.1.2. Here, it can also be read that the 16 households, of which the round-trip carsharing participation is unknown, are all living in Amsterdam.

Descriptive statistics of the variables that are available in the enriched sample, are presented in Table 21. In this table, the number of observations per characteristic is shown, just as the minimum and maximum value and the mean and standard deviation of all observations. In order to determine the mean and standard deviation of the gross household income, the ordinal classes are converted into a scale measurement, in which the median of the class represents the assumed income. Furthermore, a remark should be made on the accessibility indicators. In contrast to most indicators, these indicators are lower when the performance is better.

TABLE 19: SAMPLE DISTRIBUTION OF THE 1525 HOUSEHOLDS THAT DO NOT PARTICIPATE IN B2C OR P2P CARSHARING

	Entire sample	**No carsharing participation**			
		No car	1 car	2 cars	3 or more cars
		0n	1n	2n	3+n
n **%**	1787 100%	227 12.7%	907 50.8%	337 18.9%	54 3.0%
		Represents 98.1% of all households with at least one driving licence holder			

TABLE 20: SAMPLE DISTRIBUTION OF THE 262 HOUSEHOLDS THAT PARTICIPATE IN B2C OR P2P CARSHARING

	Entire sample	**Round-trip carsharing participation**				**Unknown, but B2C**	**Other**
		Roundtrip carsharing membership and no car	Roundtrip carsharing membership and 1 car	Roundtrip carsharing membership and 2 cars	Roundtrip carsharing membership and 3+ cars	Unknown whether round-trip or one-way carsharing member	Participating in P2P- or one-way carsharing, but no round-trip carsharing
		0rt	1rt	2rt	3+rt		
n **%**	1787 100%	102 5.7%	34 1.9%	15 0.8%	2 0.1%	16 0.9%	93 5.2%
		Oversampled: represents 1.9% of all households with at least one driving licence holder					

TABLE 21: DESCRIPTIVE STATISTICS OF THE CHARACTERISTICS PRESENT IN THE ENRICHED SAMPLE DATA

Dependent variables	N	Min.	Max.	Mean	Std. Dev.
Car ownership Number of owned cars in the household	1787	0	3 +	1.07	0.74
Round-trip carsharing participation Dummy variable: round-trip carsharing participation (1) or not (0)	1771	0	1	0.09	0.28
Land-use variables					
Urbanization degree Average household density in municipality in five categories	1787	1	5	2.29	1.27
Parking costs Average price for short stay parking in the municipality in euros	1635	0	1.95	0.70	0.74
Public transport accessibility Accessibility indicator for public transport, weighted to total travel demand towards the municipality (lower indicator = better)	1635	62.987	205.610	95.88	20.66
Car accessibility Accessibility indicator for car transport, weighted to all car travel demand towards the municipality (lower indicator = better)	1635	75.953	202.717	101.47	6.12
Density of round-trip shared cars Average number of round-trip shared cars per acre in municipality	1635	0	4.24	1.13	1.71
Supply of round-trip shared cars Total supply of round-trip shared cars in municipality	1635	0	931	223.19	382.67
Household variables					
Household size Number of persons in the household up to 6 or more	1787	0	6+	2.26	1.19
Education Education level of respondent in 8 categories	1787	-	-	-	-
Household composition Household composition in 3 categories	1787	-	-	-	-
Household income Gross household income in 27 discrete steps *Mean and standard deviation based on median of each step	1425	0 – 4,600	310,700+	48,627*	35,075*
Age Age of respondent	1787	18	92	49.71	15.63
Age partner of breadwinner Age of partner of breadwinner in 4 age categories	1374	<35	65+	-	-
Age of youngest child Age of youngest child in the household in 2 age categories	413	0-11	12-17	-	-
Other					
Green party voters % of green party voters in the municipality	1635	2.63	27.56	15.14	6.23
Carsharing awareness Dummy variable for people that have heard of carsharing before (1) or not (0)	1787	0	1	0.83	0.38
Carsharing participants in social environment Dummy variable for the presence of carsharing participants in the social environment (1) or not (0)	1787	0	1	0.26	0.44
Information available on municipality's website Dummy variable for the presence of information (1) or not (0)	1635	0	1	0.47	0.50

5.2 Specification of model structure

In this paragraph the model structure for the empirical model is specified. The model specification consists of two steps: choosing the alternatives and determining the modelling approach. In the paragraph on the modelling approach, special attention is given on how to correct for the oversampling of carsharing participants.

5.2.1 Specification of alternatives

Car ownership and round-trip carsharing membership are not mutually exclusive. In order to make use of a logit approach it is thus needed to model every possible combination of car ownership and carsharing membership. In the empirical model, therefore five alternatives are distinguished:

- Household with 0 cars and **no** round-trip carsharing membership (0n)
- Household with 1 car and **no** round-trip carsharing membership (1n)
- Household with 2 or more cars and **no** round-trip carsharing membership (2+n)
- Household with 0 cars, but with a round-trip carsharing membership (0rt)
- Household with 1 or more cars and with a round-trip carsharing membership (1+rt)

Round-trip carsharing membership is here defined as the usage of a round-trip shared car at least once a year (or at least once in the past 12 months). One could argue whether a more frequent usage is more suitable, but the sample data does not allow making another distinction. The selection of the alternatives is based on the number of observations in the sample data. There are only few observations of households with three or more cars and no carsharing membership (3+n) and therefore this group is combined with the households that have two cars in the household. The same goes for the number of observations in which car ownership is combined with round-trip carsharing membership. The number of observations for this group is rather low, and therefore it is chosen to make no distinction in the number of owned cars. Although the numbers of observations for the two round-trip alternatives (0rt & 1+rt) are still small, it is chosen not to combine them into one alternative. This is because strong differences are expected between households with and without a private car.

When the number of observations would not limit the alternative specification, it would be preferred to add two extra alternatives: households with three or more cars and no carsharing (3+n) and households with two or more cars and participating in round-trip carsharing (2+rt). In around 5.6% of the households there are 3 or more drivers present, according to the MON[15] survey is 2009. For this group, the ownership of two or three cars will actually impact the car availability and therefore the extra alternatives are expected to be relevant inputs for the mode choice model.

5.2.2 Specification of modelling approach

The choice between the alternatives is modelled by a multinomial logit model (MNL). The MNL model is selected, because it is the most straight-forward model that has the ability to correct for the oversampling of carsharing participants as present in the TNS NIPO sample. In other models it is also possible to correct for oversampled data, but applying them requires more advanced knowledge of econometrics and is beyond the scope of this master's thesis. It is however acknowledged that an MNL model is not able to account for unobserved correlations between the alternatives, which are expected to be present between the car ownership alternatives (1n, 2+n, 1+rt) and the carsharing membership alternatives (0rt, 1+rt). For future research, it is therefore advised to consider another modelling approach. Appendix H provides a brief overview of more advanced logit models that might be better suitable for the modelling of car ownership and carsharing membership.

In the MNL model of McFadden (1974), it is assumed that households have homogeneous tastes for observed alternative attributes, and that the random (unobserved) part of utility is independent and identically distributed. In an MNL model the choice set is denoted by $C(1, \dots, J)$ and the alternatives in the choice set are referred to as i, where $i \in C$. The gained utility (V_{hi}) to household h from choosing alternative i equals:

$$V_{hi} = ASC + \sum_{m} \beta_{im} * x_{hm} + \varepsilon_{ih} \qquad i = 1, \dots, J; h = 1, \dots, H$$

In the equation, ASC refers to the Alternative Specific Constant, β_{im} represents the parameters that vary per attribute (m) and per alternative, the attributes values that vary per household and per attribute are denoted by x_{hm}, and ε_{ih} represents the unobserved part of the utility.

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[15] MON: Mobiliteits Onderzoek Nederland [Mobility Survey Netherlands]. The MON is a survey towards travel behaviour, which was conducted yearly by the CBS in the time period of 2004 to 2009.

The probability that a household chooses a certain alternative is denoted as P_{hi} and depends on the utility of each of the alternatives. The relation between the probability that an alternative is chosen and the utility of the alternatives is described via the following logit function:

$$P_{hi} = \frac{e^{V_{hi}}}{\sum_{j=1}^{J} e^{V_{hj}}}$$

Correcting for choice-based samples with MNL modelling

It is in the nature of MNL model estimations, that the oversampling of households that opt for a certain alternative does not affect the value or significance level of the coefficients. The oversampling of a certain group will only result in a deviating alternative specific constant (ASC). The ASC is an alternative specific dummy variable and is included on the ground that other unmeasured factors affect the decision (Small, Verhoef, & Lindsey, 2007). An oversampled group for a certain alternative will thus result in an increased ASC for the chosen alternative. This idea originates from a footnote of McFadden in an article of Lerman and Manski (1979) and is given new attention to by De Jong (1991). Here it is described that conventional maximum likelihood estimation can be performed, as long as the following conditions apply:

- The model is multinomial logit (MNL);
- A full set of alternative specific constants is estimated (thus every alternative should have its own constant, except for one);
- The population shares of the alternatives are known.

If this is the case, a correction can be carried out for the ASCs after the estimation of the coefficients via the conventional maximum likelihood method. An important condition for this correction method is that all records within one alternative are equally under- or oversampled. The correction is described by the following formula:

$$d_i = {d_i}^0 - \ln(H_i/Q_i)$$

In which:

d_i	Constant for alternative i after correction
${d_i}^0$	Constant for alternative i, as estimated via MNL model estimation
H_i	The proportion in the sample choosing i
Q_i	The proportion in the population choosing i

The correction is performed iteratively: the corrected ASC's are placed in the utility function and an apply run is conducted to check whether the estimated sample shares meet the true population shares. An apply run involves the application of the estimated MNL model on (a representative sample of) the total population. The sample that is used for this correction could thus be any sample that includes information on all attributes in the MNL model and that is representative for the population. During this study, the original TNS NIPO sample is used, which is made representative with the help of weighting factors. If the estimated sample shares do not meet the true population shares, the ASC's are corrected according to a similar formula:

$$ {d_i}^{n+1} = {d_i}^n - \ln({H_i}^n/Q_i)$$

In which:

${d_i}^{n+1}$	Constant for alternative i after n+1 corrections
${d_i}^n$	Constant for alternative i, after n corrections
${H_i}^n$	The estimated sample share choosing i, applying constant ${d_i}^n$
Q_i	The proportion in the population choosing i

UNAWARENESS OF CARSHARING ALTERNATIVE

The specification of the alternatives and the modelling approach, has led to the model structure that is shown in Figure 13. The model structure shows an objective choice set; it covers all alternatives that are considered to be logical. During this study only respondents aware of the carsharing alternative are faced with the full choice set of five alternatives. For the respondents unaware of carsharing, only the alternatives that do not include carsharing are available. In this way, the effect of an increased awareness of carsharing can be tested via scenario studies. It is hereby implicitly assumed that the awareness of the respondent is a good measurement for the awareness of the household.

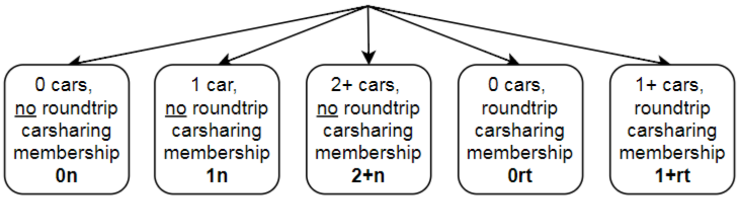

FIGURE 13: MODEL STRUCTURE

5.2.3 SPECIFICATION OF VARIABLES

An overview of the variables that are available for empirical modelling is given in Appendix I. In this overview the measurement scale is presented and the categories in case of nominal, ordinal or interval variables are defined.

During this study, for all variables that are measured on a ratio scale, a linear relation with the dependent variables is assumed. The assumption of a linear relation is a common use in social studies, because the actual relationship between empirical variables is often hard to determine and if a linear relation is found to be a valid display of the relationship, it is not possible to construct a simpler model with a higher explanatory ability (Faber, 2000).

5.3 EMPIRICAL MODEL ESTIMATION

This paragraph describes the empirical model estimation. First a short introduction is given on the data transformations that are conducted to prepare for the empirical modelling. Next, the estimation process is described. The paragraph concludes with the MNL modelling results.

5.3.1 DATA TRANSFORMATION FOR EMPIRICAL MODELLING

This subparagraph discusses the data transformations that are performed to prepare the provided data for empirical modelling. First, the transformations as a result of the distribution of the records over the alternatives are discussed. Next, it is discussed how to deal with the incomplete records, where information on income or municipality is missing. Last, transformations in attribute specification are pointed out.

DISTRIBUTION OF RECORDS OVER THE ALTERNATIVES

The distribution of the sample records over the five alternatives as specified in paragraph 5.2.1, is shown in Figure 14. As can be seen, households participating in P2P and/or one-way carsharing (but not in round-trip carsharing), are eliminated from the sample. Furthermore, all people of which it is unknown whether they participate in one-way or round-trip carsharing, are assumed to participate in the latter carsharing type. Below, both sample transformations are substantiated and discussed.

The elimination of the households participating in other forms of carsharing (93 records in total) is a result of the conditions for ASC correction in choice-based samples. As informed earlier, the sample data contains an oversampling of carsharing participants of B2C and P2P organizations. In order to account for the oversampling an ASC correction is applied afterwards, but an important condition for this correction method is that all records within one alternative are equally under- or oversampled. Households that are participating in P2P- and one-way carsharing (oversampled), but not in round-trip carsharing, can thus not be combined with the households that do not participate in any form of carsharing (under sampled). In this study, it is chosen to eliminate all oversampled records that do not participate in round-trip carsharing. It is acknowledged that this will affect the representativeness of the complete sample, but the effect is assumed to be marginal: only 0.67% of the complete population is participating in other types of carsharing than round-trip carsharing compared to 98.1% of the population that is not participating in any form of carsharing.

The decision to transform all B2C carsharing participants of which the carsharing type is unknown (16 in total) into round-trip carsharing participants, results from the assumption that elimination of the records would lead to a worse sample. The households, of which the carsharing type is unknown, are all located in Amsterdam. Based on the remaining households in Amsterdam, it is assumed that around 75% of the B2C carsharing participants are participating in round-trip carsharing. Adding the unknown households to the round-trip carsharing participants, is thus expected to lead to a slight oversampling of Amsterdam households among round-trip carsharing users, but eliminating them would lead to a larger under sampling.

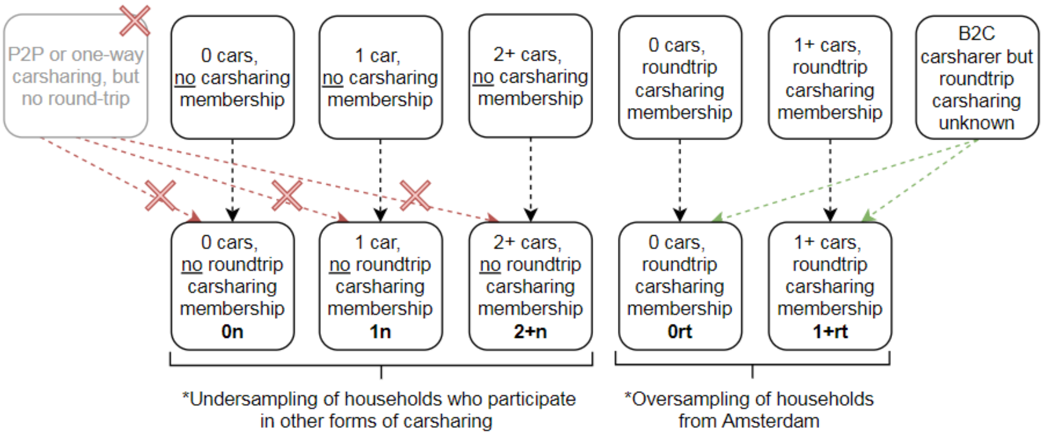

FIGURE 14: DISTRIBUTION OF THE SAMPLE RECORDS OVER THE ALTERNATIVES

INCOMPLETE RECORDS

Table 18 showed that part of the records does not contain information on the household income or externally linked municipality related characteristics. In this study, it is decided to eliminate all records of which the municipality is unknown and to estimate a dummy for all households of which the gross household income is unknown.

The decision to exclude the respondents, of which the municipality is unknown, is made because nine of the variables are based on the municipality the respondent is living in, which is almost half of the total number of variables to test for. It is assumed that the households of which the municipality is unknown, are randomly distributed over the sample and will thus not affect the representativeness of the sample.

For the income variable, a dummy is estimated for all households of which the gross household income is unknown. Elimination of the records is not preferred in this case, because on one hand it would lead to a large reduction of the already scarce sample and on the other hand it is expected that the respondents of which the income is unknown, are not randomly distributed over the sample. Households with relatively high or illegally gained incomes are assumed to be more likely to silence about their income.

The elimination of the records of which the municipality is unknown, leads to the exclusion of 145 records, on top of the 93 records that were already excluded because they could not be distributed over the alternatives. Because of the exclusions, the sample size is reduced to N=1549. The distribution of the sample over the five alternatives is shown in Table 22. The population shares in the table are based on the approximated population shares as determined in Appendix J.

TABLE 22: DISTRIBUTION OF MODEL ALTERNATIVES IN SAMPLE DATA FOR ALL RECORDS OF WHICH MUNICIPALITY IS KNOWN

	Entire sample for estimation	**No round-trip carsharing membership**			**Round-trip carsharing membership**	
		Households with no car	Households with 1 car	Households with 2 cars	Roundtrip carsharing membership and no car	Roundtrip carsharing membership and 1 car
		0n	1n	2+n	0rt	1+rt
n	1549	199	834	364	103	49
		Represents 98.77% of all households with at least one driving licence holder			Represents 1.23% of all households with at least one driving licence holder.	

TRANSFORMATIONS IN ATTRIBUTE SPECIFICATION

In the attribute specification, some transformations are made to ease or enable the empirical modelling:

- Age
  In the sample data, the only age measurement on household level is the 'age of the partner of the breadwinner'. This measurement is however only available for the adult households. For the households with children, the age of the respondent is used instead. This transformation relies on the assumption that adult household members are of similar age. An exception is made when the respondent is under the age of 30 and living in a household in which the youngest child is in the age group of 12 to 17. In those cases, the age of the respondent is put up by 30 years, which equals the average age of parents at the birth of their first child in the mid 90's (CBS, 2017c). Statistics on the age of both parents were not available for earlier years.
- Accessibility indicators
  Both the public transport- and the car transport accessibility indicator are multiplied by a factor of '-1'. In this way, a higher number indicates a higher accessibility, which eases the model.
- Income
  The gross household income is originally measured via an ordinal scale in 27 discrete steps. For the empirical modelling, the income is transformed into a ratio scale and the median of every income category is used instead. For the highest income category (310,700+), the value of the lower bound is used.

5.3.2 ESTIMATION PROCESS

The estimation process is an iterative process in which various combinations of variables and parameters are tested. First of all, a 'full model' is estimated, which includes all variables that are available in the sample data. The full model gives information on the correlations that are present among variables and moreover provides first insights in the effect of the variables on either car ownership or carsharing participation.

Next, the 'best possible model' is set up via a step-by-step approach, see also Figure 15. It is started with a simple model that only includes few parameters and in every new model extra parameters are added. For each model, it is evaluated whether the parameters are interpretable and reliable (Alafi, 2017). Interpretable means that the parameter signs are in line with expectations. Reliable refers to the extent to which the parameter is statistically significant, meaning that it significantly differs from zero within a 95% confidence interval. When the parameters are both interpretable- and reliable, the model is compared to the previous best model based on the McFadden's rho-squared (ρ^2). The McFadden's rho-squared is calculated by the following equation:

$$\rho^2 = 1 - \frac{LL_\beta}{LL_0}$$

where LL_β denotes the likelihood value of the estimated model and LL_0 denotes the 0-log-likelihood; when all parameters would equal 0. The ρ^2 thus quantifies how much better the model is than simply 'throwing a dice' (Chorus, 2016). The closer to 1, the better the model fit. When including only additional free parameters and not eliminating any other parameters, the model fit is by definition higher. In those cases, it is tested whether the increased model fit is also statistically significant (and not only due sample peculiarities) via a Likelihood Ratio Test, which is based on the Likelihood Ratio Statistic:

$$LRS = -2 \cdot (LL_A - LL_B)$$

where LL_B denotes the likelihood value of the newly estimated model and LL_A denotes the likelihood of the previously estimated model. If the test statistic is higher than a certain threshold (based on the number of additional free parameters and the chosen confidence interval), the new model is statistically better. Based on whether the new model has a statistically better model fit, the new model is kept or discarded and then the cycle starts again with the development of a new model. The iterations stop when after various explorations no better model can be found anymore, or when all possible parameters are included in the model.

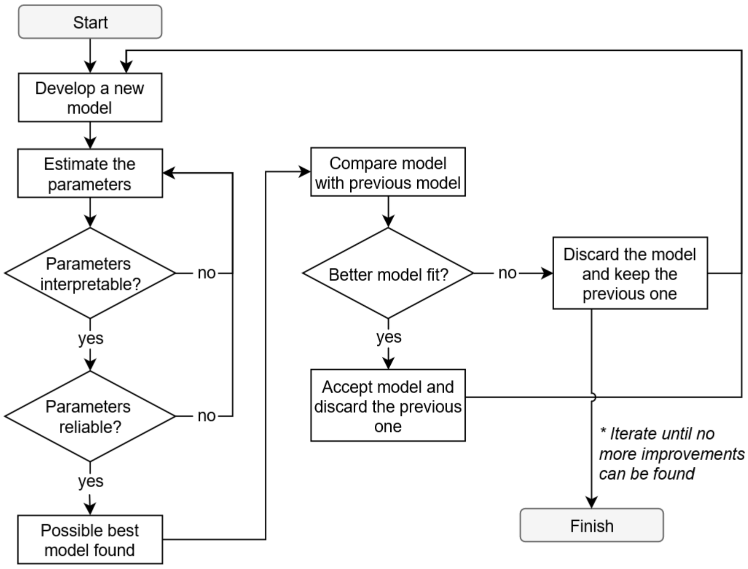

FIGURE 15: MODEL'S SELECTION METHOD. ADAPTED FROM (ALAFI, 2017).

In order to estimate a new developed model, statistical software (ALOGIT version 4) is used. ALOGIT is a computer program for studying and forecasting consumer choices (ALOGIT Software & Analysis Ltd., 2007). The parameter estimation in ALOGIT is based on the Maximum Likelihood-principle: the software searches the parameter values that maximize the likelihood, given the observations. The estimation method is not further specified in the technical documentation, but it is stated that the estimation algorithm stops as soon as convergence is reached (convergence level = 0.01) or when the maximum number of iterations is performed (max = 50). For all estimated models presented in this report, convergence is reached in less than 50 iterations.

5.3.3 MNL MODELLING RESULTS

In this paragraph, first the model results are presented and evaluated, where after the development of the best possible model is amplified. Apart from the two models (full model and best possible model) presented in this paragraph, a third model is estimated, which is attached in Appendix O. This third model is a re-estimation of the best possible model, based on a larger set of observations. Here, also the observations of which the municipality is unknown, are used for the estimation. The re-estimation was conducted, because the best possible model merely includes land-use variables that are retrieved from external data sources and linked via the municipality.

PRESENTATION OF MODELLING RESULTS

Table 23 and Table 24 present the MNL modelling results of the full model and the best possible model. The full model includes all 15 variables that are present in the enriched sample and are hypothesized to have an influencing effect on either car ownership or round-trip carsharing participation. The best possible model is based on the model results of the full model and constructed via a step-by-step approach. In the best possible model, the ASC's are corrected for the oversampling of carsharing participants. The computation of the correction factor is attached in Appendix J.

The full model and the best possible model are estimated on all observations of which the municipality is known (N=1549) and are estimated based on the same reference alternative '0n': no car ownership and no round-trip carsharing participation. The model results show that explanatory variables are present, although only a limited number of parameters are found to be statistically significant in the full model. Parameters that are estimated in both models have more or less of the same value. In both models a dummy variable is added for households living in Amsterdam, because this group is oversampled in the data and has influenced the estimation results. An estimation of the full model without the Amsterdam dummy variable was found to result in rather deviating parameters for the urbanization degree, the parking costs and the supply of shared cars, see also Appendix K.

The full model and the best possible model differ around 30 points in log likelihood, while the difference in degrees of freedom is 48. The suspicion is raised that this difference is significant, but it cannot be tested via a Likelihood Ratio Test (LRS Test), because the full model is not nested in the best possible model, due to slightly altered variables. To be able to compare the models, an alternative version of the full model is estimated, in which only additional free parameters compared to the best possible model are included, see also Appendix K. Based on this model, it is concluded that the full model does not have a significant better model fit (p>0.05) than the best possible model.

TABLE 23: FULL MODEL (N=1549 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). RESPONDENTS OF WHICH MUNICIPALITY IS UNKNOWN ARE EXCLUDED. MNL MODELLING APPROACH. REFERENCE: 0N (NO ROUNDTRIP CARSHARING, NO CAR). RESPONDENTS AWARE OF CARSHARING (1267) WERE FACED WITH THE COMPLETE CHOICE SET, FOR THE OTHER HOUSEHOLDS (282) ONLY THE ALTERNATIVES 0N, 1N AND 2+N WERE AVAILABLE. SIGNIFICANT PARAMETERS (P<0.05) ARE MARKED IN BOLD.

Number of observations	1549
Final log likelihood	-1389.3
Degrees of Freedom	83
Rho²(0)	0.409

	1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*	3.661	*1.8*	-1.135	*-0.5*	-8.084*	*-1.8*	-5.802*	*-0.9*
Dummy: Living in Amsterdam	-0.966	*-1.8*	-1.278	*-1.3*	**-11.240**	*-3.0*	-4.229	*-0.8*
Household size	0.110	*0.5*	0.544	*0.5*	-0.040	*-0.1*	**0.761**	*2.7*
Dummy: Single household	**-1.830**	*-2.9*	**-2.265**	*-2.3*	-1.225	*-1.3*	-1.217	*-1.2*
Dummy: Adult household multiple persons	**-1.260**	*-2.8*	-0.272	*-0.3*	-0.852	*-1.3*	-0.813	*-1.2*
ref: household with kids								
Dummy: Partner breadwinner of household <35	**-1.669**	*-5.6*	0.234	*0.2*	0.843	*1.5*	-0.065	*-0.1*
Dummy: Partner breadwinner of household 35-39	**-1.709**	*-4.5*	-0.231	*-0.2*	0.310	*0.5*	**-2.621**	*-2.2*
Dummy: Partner breadwinner of household 40-49	**-0.936**	*-3.1*	0.675	*0.7*	0.698	*1.2*	-0.494	*-0.7*
Dummy: Partner breadwinner of household 50-64	**-0.522**	*-2.1*	0.670	*0.7*	0.963	*1.8*	-0.223	*-0.4*
ref: Partner breadwinner 65+								
Gross household income (x 100.000)	**1.845**	*3.5*	**3.460**	*3.5*	**2.382**	*3.7*	**3.077**	*4.5*
Dummy: income unknown	**0.814**	*2.8*	**2.011**	*2.0*	0.843	*1.9*	**1.233**	*2.0*
Dummy: HBO+ education	0.188	*1.0*	0.279	*0.3*	0.091	*0.3*	**1.015**	*2.4*
Dummy: Carsharing participants in social environment					**2.794**	*9.3*	**2.993**	*7.2*
Dummy: Urbanization degree 1 (>2,500 hh/km²)	-0.864	*-1.3*	-1.798	*-1.8*	0.295	*0.4*	-0.402	*-0.4*
Dummy: Urbanization 2 (1,500 - 2,500 hh/km²)	-0.735	*-1.3*	-1.288	*-1.3*	0.596	*1.0*	-0.309	*-0.5*
Dummy: Urbanization 3 (1,000 - 1,500 hh/km²)	-0.569	*-1.0*	-0.891	*-0.9*				
Dummy: Urbanization 4 (500 - 1,000 hh/km²)	-0.352	*-0.6*	-0.333	*-0.3*				
ref: urbanization degree 5(<500 hh/km²)								
Indicator public transport accessibility	-0.006	*-0.9*	-0.014	*0.0*	0.019	*1.3*	0.000	*0.0*
Indicator car transport accessibility	0.004	*0.2*	0.009	*0.0*	-0.036	*-1.3*	0.006	*0.2*
Percentage of green votes in municipality	-1.452	*-0.4*	**2.194**	*2.2*	8.950	*1.2*	-2.268	*-0.3*
Average price for short stay parking in the municipality	-0.011	*0.0*	-0.215	*-0.2*			0.159	*0.2*
Total number of round-trip cars in municipality					**0.015**	*2.7*	0.005	*0.7*
Density of round-trip cars in municipality					-1.076	*-1.5*	-0.628	*-0.7*
Dummy: Carsharing information available on municipality's website					-0.243	*-0.5*	0.270	*0.5*

*The ASC's are calibrated to account for the oversampling of carsharing users.

TABLE 24: BEST POSSIBLE MODEL (N=1549 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). RESPONDENTS OF WHICH MUNICIPALITY IS UNKNOWN ARE EXCLUDED. MNL MODELLING APPROACH. RESPONDENTS AWARE OF CARSHARING (1267) ARE FACED WITH THE COMPLETE CHOICE SET, FOR THE OTHER HOUSEHOLDS (282) ONLY THE ALTERNATIVES 0N, 1N AND 2+N ARE AVAILABLE. SIGNIFICANT PARAMETERS (P<0.05, T-STATISTIC >1.96) ARE MARKED IN BOLD.

Number of observations	1549
Final log likelihood	-1418.5
Degrees of Freedom	35
$Rho^2(0)$	0.396

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.667**	*4.3*	**-2.464**	*-5.7*	**-7.23***	*-6.2*	**-9.48***	*-9.1*
Dummy: living in Amsterdam	**1.192**	*5.4*								
Number of adults in the household			**0.353**	*2.4*	**1.263**	*7.6*	0.236	*1.0*	**1.407**	*5.6*
Number of children in the household			**1.023**	*4.7*	**1.106**	*5.1*	**0.602**	*2.2*	**1.226**	*4.9*
Dummy: Age partner breadwinner <40			**-1.610**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.982**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.553**	*-2.8*						
Dummy: Age partner breadwinner 40-64					**0.416**	*2.1*				
Dummy: Age partner breadwinner <64							**0.999**	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.165**	*4.4*	**3.893**	*7.4*	**2.512**	*4.2*	**3.172**	*4.9*
Dummy: income unknown			**0.914**	*3.2*	**2.125**	*6.4*	**0.791**	*1.8*	**1.227**	*2.1*
Dummy: HBO+ education									**0.902**	*2.4*
Dummy: Carsharing participants in social environment							**2.856**	*10.0*	**3.052**	*7.5*
Dummy: Urbanization degree 1			**-0.938**	*-3.0*	**-2.194**	*-6.3*			**-0.707**	*-1.9*
Dummy: Urbanization degree 1 and 2							**0.988**[E]	*2.5*		
Dummy: Urbanization degree 2 and 3			**-0.663**	*-2.4*	**-1.223**	*-4.1*				
Ref: Urbanization degree 4 and 5										

*The ASC's for the round-trip carsharing alternatives are calibrated to account for the oversampling of carsharing users.

From the parameter estimation reported in Table 24, one can observe the relatively strong and positive effect of the presence of carsharing participants in the social environment on round-trip carsharing participation. Higher education is also found to have a positive effect on carsharing participation, but it is interesting to notice that the expected positive effect of high education on round-trip carsharing participation only shows for the alternative in which car ownership and carsharing participation are combined. A possible explanation for the fact that the education is not found to be significant in the 0rt alternative, might be found in the actual consideration that is made. The explanatory character of the education level is assumed to be an effect of the higher environmental concern (Economic and Social Research Council, 2011). This means that carsharing is preferred, when it is more environmentally friendly than the other alternative, which implies that it is compared with the purchase of an additional car. It might be that the 1+rt alternative is more often considered as an alternative for 2n instead of 1n, and that the 0rt alternative is in contrast more often considered as an alternative for 0n. It should be emphasized that this idea is only based on the author's insights and further testing is thus needed, be it with other data or with the help of more advanced logit models that take unobserved correlations between the alternatives into account.

The parameters for household size (number of adults and number of children) and household income give expected results: the more people and the higher the income, the more utility is derived from alternatives that provide higher car availability. The parameter for the number of adults for the 0rt alternative is not significant, but the parameter value is in line with expectations and assumed to hold when estimated on a larger set of observations.

Regarding the age variables, it is in line with expectations that households in the category 65+ are most often opting for 1 car without carsharing membership. It was furthermore expected that younger people are more often participating in round-trip carsharing, but this does not show. It is only found that households aged 65 and over are less often participating in carsharing, as long as it is not combined with car ownership. For the combination of car ownership and carsharing membership, no impact of the age of the household is found.

Lastly, the parameters for the urbanization degree are in line with expectations. Car ownership is less favoured in highly urbanized regions and if car ownership is chosen, the alternatives with fewer cars are preferred.

JUSTIFICATION OF THE DEVELOPMENT OF BEST POSSIBLE MODEL

The development of the best possible model is based on the estimation results of the full model and an iterative empirical modelling process. During the empirical model process, the correlations that are present between the variables are taken into account. A correlation table is attached in Appendix L.

Based on the model results of the full model, it is first of all decided to eliminate the variable that represents the '*percentage of green party votes in the municipality*'. The variable functioned as a proxy for the environmental concern, but the only significant parameter found in the full model, was a positive one for the most polluting alternative (2+n). It is therefore concluded that this variable is a rather poor proxy. According to a similar line of reasoning, furthermore the dummy variable for '*the presence of carsharing information on the municipality's website'* is eliminated. Moreover, the variable for '*car transport accessibility'* is eliminated, because the estimated parameters in the full model were small and insignificant, while no strong correlations with other variables were present.

The inclusion or elimination of the remaining variables is determined via an empirical modelling process. For the variables that were found to correlate strongly, various combinations are tested in smaller sub models and then compared based on their log likelihood andρ^2. In order to consolidate the sub models into a final model, a step-by-step approach is used, which means that first a model is estimated with only alternative specific constants and new sub models are estimated for the addition of every new variable. After the addition of a (group of) variable(s), the results are evaluated. Do the parameters of the added variables have the expected sign and what are the impacts on the other parameters? Furthermore, LRS-tests are conducted for every new model to determine to which extent the addition of extra variables has led to a significant better model fit.

In the development of best possible model, it is first of all decided to replace the household size and household composition variables for two new variables: the number of adults and the number of children. For the deduction of these variables, a series of assumptions had to be made, which are described in Appendix M. The adaption is made, because in the full model considerable correlations were found between the coefficients of household size and of single- and multiple person households. Two other alternatives were tested (1. only household size; 2. number of adults and dummy for presence of children), but these alternatives resulted in a worse model fit. From an explanatory point of view this seems logical, because the number of children in the household is expected to affect the total car travel demand. Including the household size partly covers this issue, but the number of adults is assumed to have a higher effect on the total car travel demand than the number of children has.

The correlation table in Appendix L shows another set of variables that are strongly correlating: *'urbanization degree'*, '*parking costs'*, '*round-trip supply'*, '*density of round-trip shared cars', 'public transport accessibility*' and the '*dummy for living in Amsterdam'*. In the final model, it is decided to only include the dummy variable for Amsterdam and the urbanization degree.

The dummy for Amsterdam is included for the 0n alternative, because the data showed that this alternative is much more popular in Amsterdam than in other highly urbanized regions, taking into account the household characteristics such as age, income and household size. Especially because the 0n alternative is the reference alternative, this has significant impact on the model estimations. Apart from the popularity of the 0n alternative, the rather deviating parking costs and supply of round-trip shared cars compared to other municipalities were also arguments to include a separate dummy for Amsterdam. Parking costs are almost twice as high as in the second most expensive municipality and the round-trip supply is around five times as high as in the municipality with the second most supply.

It is chosen not to include the parking tariffs, because the variable was found to lose its explanatory ability as soon as a dummy variable for Amsterdam was included. The parking prices variable functioned as a proxy for the ease of parking and the fact that this variable did not show significant parameters, might thus imply that in other municipalities parking regulations do not play a role in the decision process. This conclusion is however doubted, since averages on municipality level are used, while prices vary largely among the municipality. Moreover, it is questionable whether parking prices are a good proxy for the ease of parking. Higher parking prices on one hand imply that there is more competition for the available parking spots, but on the other hand parking prices are often implemented to increase the parking availability for the residents by chasing away cars of visitors.

Furthermore, it is decided to eliminate the variable for '*the density of round-trip shared cars'*, because the variable is almost fully correlating with the supply variable (0.99) and separate sub modelling showed that the supply had a better explanatory ability.

From the remaining correlating variables (urbanization degree, round-trip supply and public transport accessibility) it is decided to only include the urbanization degree. The inclusion of all three variables led to unexpected signs due to highly correlating parameters. In order to decide which variables to include, the following alternatives were tested (see also Appendix N for the modelling results):

- Alternative 1: Round-trip supply and public transport access
- Alternative 2: Urbanization degree and public transport access
- Alternative 3: Urbanization degree and round-trip supply
- Alternative 4: Urbanization degree only

The first alternative was clearly outperformed by the others and the second alternative did not result in a significant better model fit than the fourth alternative. Significant parameters for the public transport access variable showed up, but at the expense of less significant values of the urbanization degree variable. The third alternative was actually found to result in a statistically better model fit, but here a negative parameter showed up for the number of shared cars in the 1+rt alternative. In the application of the model, an increased supply would thus lead to a reduced number of households opting for the 1+rt alternative, which is not in line with expectations. The negative parameter can however be explained, because in this sub model no parameters were estimated for the urbanization degrees in the carsharing alternatives. The urbanization degree and the supply however correlate (-0.59) and the supply parameter in the third alternative therefore also captures the effects of the urbanization degree. More shared cars per municipality relate in general to a higher urbanization degree, which is found to have a negative relation with car ownership. It is thus not the increased supply of shared cars that supressed the popularity of the 1+rt alternative, but rather the increased urbanization degree. Therefore, alternative 4 is selected, in which only urbanization degree is included.

For the inclusion of the age variable, various combinations of categories are tested. Based on the model results of the full model and additional empirical modelling, it was concluded that the distinction in five levels was not relevant, because the differences between two sequential levels were often small or non-existing, or the number of observations was too low to distinguish significant differences. Therefore, some of the variables are combined into new variables. The age of the 1+rt group was found to not significantly differ from the 0n group. The outlier in the full model for the age group 35-39 is ignored, because it is not in line with expectations or with the results in the adjacent age categories.

The dummy variable for 'carsharing participants in the social environment' remained unchanged compared to the full model, just as the income variable. No adaptions are made, because the explanatory character was strong and in line with expectations for all parameters. For the income variable, it was tested whether the use of income categories would improve the model, but this was not the case. Last, the education dummy is included, but only for the 1+rt alternative, because no significant results were found for the other categories.

5.4 Conclusion

The aim of this chapter was twofold. On one hand, this chapter aimed to determine to what extent the conceptual model could be operationalized into an empirical model with the data that is currently available, and on the other hand this chapter aimed to test whether the conceptual model is a valid representation of the reality. Below, both questions are answered one after the other.

> *"To what extent can the conceptual model be operationalized into an empirical model with the data that is currently available?"*

In this chapter, it is found that the conceptual model could only to a limited extent be operationalized into an empirical model. The available data was found to limit the operationalization in various ways. First of all, the choice-based nature of the sample data limited the modelling approach and as a result the empirical model **could not capture correlations between (unobserved) utilities of alternatives**. Moreover, the total number of observations was rather limited. Hence, **effects of various correlating variables could not be told apart** and car ownership could only be estimated up to 2 or more cars, and in case of carsharing participation only up to 1 or more cars. Last, the data only contained information on part of the hypothesized explaining variables and as a result the effect of **numerous hypothesized explaining variables could not be tested**. Major shortcomings of the available data were the lack of information on car travel demand, occupation and employment. Besides, information was missing on many land-use variables and the level of detail of the household's living address (municipality) was found to be too aggregated to successfully link external data sources.

Despite the shortcomings, the data made it possible to estimate a **MNL model on household level with five alternatives**: no car and no carsharing participation (0n); 1 car and no carsharing participation (1n); 2 or more cars and no carsharing participation (2+n); no car and carsharing participation (0rt); and 1 or more cars and carsharing participation (1+rt). The variables that could be empirically tested in the MNL model, are represented in Figure 16.

> *"Is the conceptual model a valid representation of the reality?"*

Based on the empirical modelling results, one is only able to evaluate part of the conceptual model. Figure 16 shows the hypothesized relations and indicates whether they are confirmed or rejected.

In line with expectations, carsharing awareness and the presence of carsharing participants in the social environment were found to have a positive effect on carsharing participation. Next, household income, household size and number of children were found to have a positive relation with both car ownership and carsharing participation, which was also hypothesized in the conceptual model.

In Figure 16 two relations are shown that could only partly be confirmed: education level and age on carsharing participation. The empirical model results showed that education was found to have a positive effect on carsharing participation, but this only showed for the people who combine carsharing with car ownership. No significant effect was found of education on the '0rt' alternative. In contrast, the age was primarily found to be an explaining factor for households only participating in carsharing. The results showed that households aged 65+ were indeed less often participating in carsharing; but this only showed in the '0rt' alternative. Among the people that combine car ownership with carsharing participation, no impact of age was observed. Moreover, it was hypothesized that younger people (<35) would also less often participate in carsharing, but based on the modelling results, this hypothesis should be rejected.

Next, two more hypothesized relations in the conceptual model are found to be incorrect according to the empirical modelling results. Car accessibility is not found to play a role, just as the carsharing information that is provided by the municipality.

Last, the figure shows numerous relations that were tested, but could neither be confirmed, not rejected. This is primarily the case for the proxies that were derived from external data sources and linked via the municipality the respondent was living in. In some cases, the proxy turned out to be a poor proxy for the original variable. Therefore, no conclusions can be drawn on the actual impact of the environmental concern (proxy: percentage of green party votes in the municipality) and the ease of parking (proxy: average price for short stay parking in the municipality) on car ownership and carsharing participation. Moreover, various proxies are used that are found to highly correlate with each other: Average density of shared cars (proxy for distance to nearest shared car), total number of shared cars in the municipality (proxy for number of shared cars within walking distance), urbanization degree (proxy for distance to work and facilities) and the average public transport accessibility of the municipality (proxy for public transport accessibility). It can therefore poorly be concluded which land-use variable(s) are actually impacting the car ownership and round-trip carsharing participation.

The empirical analysis did not give cause to assume that the other relations in the conceptual model are incorrect, because they could not be tested with the data available.

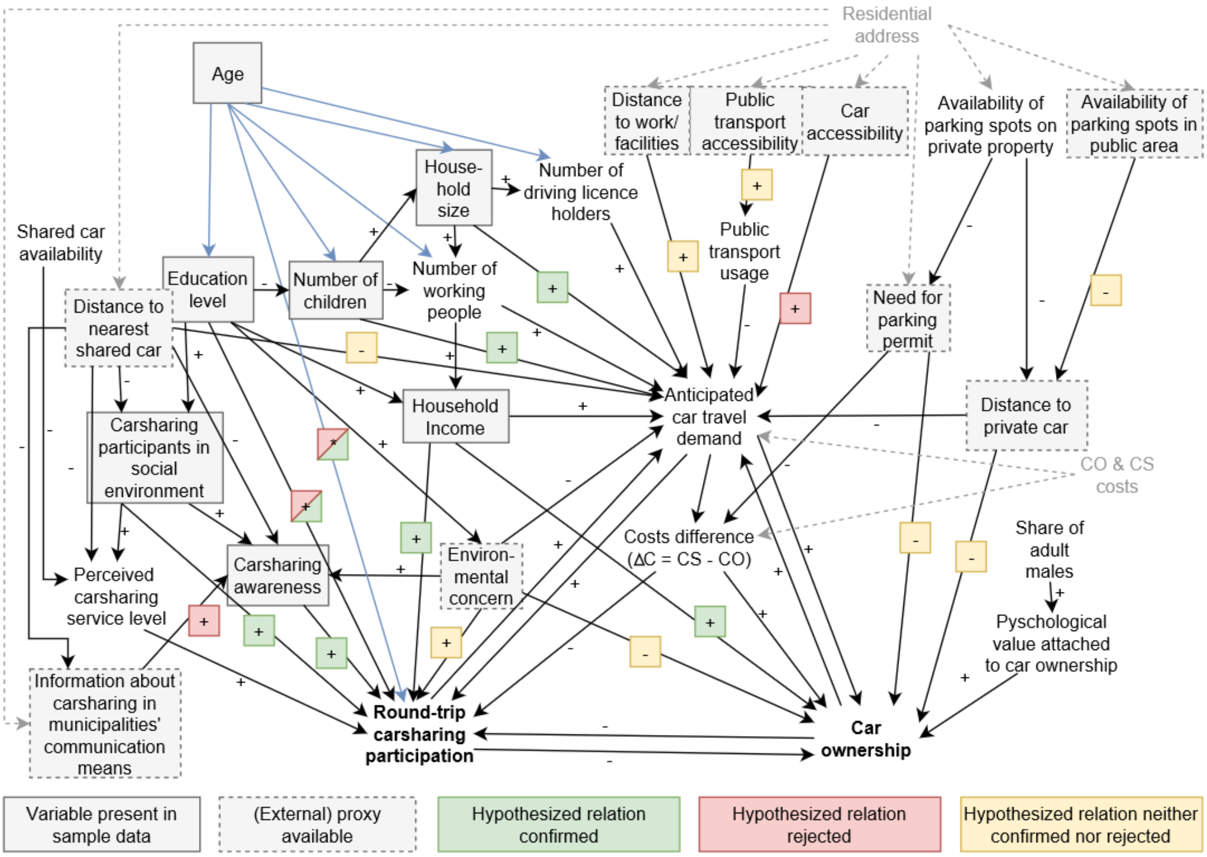

FIGURE 16: EVALUATION OF THE CONCEPTUAL MODEL

5.5 Evaluation of the empirical model

In this chapter it is aimed to design the best possible model with the data that was provided. There are however various remarks to make on the provided data and the design process. The interpretation of the best possible model should thus be done with concern.

First of all, it should be emphasized that adaptions are made to the sample data. Due to poorly formulated questions in the TNS NIPO survey, contradicting responses were found and as a result round-trip carsharing participation could not always be deduced with certainty. Therefore, some households might have been incorrectly labelled as round-trip carsharing participants. Moreover, uncertainty comes in for some of the explanatory variables: the age of the partner of the breadwinner, the number of adults, and number of children. For some records, these variables were not clear from the survey and therefore assumptions are made. The assumptions could however be false and might thus have impacted the model results.

Moreover, it is questionable whether the used definition of round-trip participation is the best one. The data only allowed us to draw the line at the usage of a shared car at least once a year. For future research, it would be interesting to test other frequencies. If somebody used the shared car only once in the last year, it is highly questionable if the person should be considered as a carsharing participant. Carsharing could have been a one-time solution for the movement of furniture or the user might have been disappointed and will no longer participate in round-trip carsharing.

Next, the best possible model does not include any land-use variables, apart from the urbanization degree and a dummy for living in Amsterdam. The fact that most land-use variables did not contribute to a better model fit, does not mean that they did not play a role in the decision. It is plausible that the scale, on which the variables were measured, was too large. Public transport accessibility can vary largely within a municipality, just as parking prices and the density of shared cars (as a proxy of access distance). Furthermore, there was an uncertainty in the determination of the municipality: as long as people moved to another municipality with the same urbanization degree and within the same province, this is not noticed and the new municipality is thus incorrectly used to link external data sources.

Last, a remark should be made on the income variable. Officially, the gross household income is the gross income from all sources, before deductions for tax, superannuation, et cetera. Allowances for expenses, social benefits and profit distribution are thus also part of the gross household income. It is however questionable to what extent all these different income sources are actually kept in mind when filling in the survey. The actual gross household income might thus differ.

CHAPTER 6

6 MODEL APPLICATION: SCENARIO STUDIES

In this chapter it is tested how carsharing might change in the future under various scenarios. Literature study has shown that the current usage of shared cars is marginal in relation to other transport modes. Hence, the relevance of modelling carsharing in strategic travel demand models is primarily motivated by the expected growth of carsharing towards the future. The growth expectations are however only based on extrapolations over the past few years, and do not take into account variables that might limit the growth.

This brings us to the aim of the chapter: Exploring how round-trip carsharing participation might change in the future under various scenario's via empirical model application. Model application makes it possible to analyse complex systems that are affected by numerous variables. The scenario studies help to gain a better understanding in the effect of changes in the population or the built environment on car ownership and round-trip carsharing participation. It is hereby particularly interesting to test to what extent changes will result in increased round-trip carsharing participation, since this will help us to determine the carsharing market potential. The larger the market potential, the higher the relevance of its modelling in strategic travel demand models.

The scenario studies are performed via application of the best possible model that is constructed in the previous chapter. The scenario outcomes are compared with an application of the model on a representative reference scenario. In this study, a weighted version of the TNS NIPO sample is used for the reference scenario. The weighting is performed according to the weighting factors that are determined in Appendix J.

This chapter starts with the design of the scenarios, where after the outcomes of the scenario studies are presented and discussed.

6.1 SCENARIO DESIGN

The scenarios are designed such that one is able to test to what extent round-trip carsharing participation might grow towards the future. Therefore, only scenarios are designed in which it is expected that carsharing participation will grow. Moreover, the scenario design is limited to the adaption of variables that are present in the empirical model. The following scenarios are designed:

1. **Increased awareness**
   When the awareness is increased, a larger number of people will consider carsharing participation. In modelling terms, this means that a larger number of people is faced the full set of alternatives. To test to what extent this indeed leads to a larger number of carsharing participants, in scenario 1 it is now assumed that everybody is aware of carsharing and thus faced with the full set of alternatives. In the reference run, people unaware of carsharing are only faced with alternative 0n, 1n, and 2+n.
2. **Increased carsharing usage in social environment**
   The best possible model showed that the presence of carsharing participants in the social environment has a strong and significant effect on carsharing participation in the household. Round-trip carsharing participation will thus grow as the usage in the social environment increases. In Scenario 2 it is tested what the population distribution will look like when everybody knows a carsharing participant in their social environment. In this scenario, it is also assumed that everybody is aware of carsharing and every household is thus faced the full set of alternatives.
3. **Urbanization**
   Based on the best possible model, one can conclude that urbanization will lead to reduced car ownership and increased usage of round-trip carsharing. In order to determine the size of this effect, an extreme

scenario is designed: the household density in every municipality is increased, such that the urbanization degree is changed with one level. Households that are living in a municipality with an urbanization degree of level 5 in the reference sample, are thus in the scenario living in a municipality with urbanization degree 4. It is acknowledged that this scenario is rather unlikely: urbanization will in practice lead to a lower household density in rural areas and only an increased household density in urbanized areas. The aim of the scenario is however to test to what extent an increased population density will affect the carsharing participation.

4. **Increased financial prosperity**
   Last, the impact of increased financial prosperity is measured. In this fourth scenario, the gross household incomes are increased with consecutively 10% and 20%.

The empirical model also allows us to test for changes in the education and the age, but this is not considered relevant. More highly educated people will lead to an increased number of people combining car ownership with carsharing participation, but it is not expected that the average education level will change in the nearby future. In contrast, the average age is expected to change, since the population is ageing. An ageing population will however result in less carsharing participation, while the scenarios aim to quantify to which extent changes in the variables might increase carsharing participation. A rejuvenation of the population would thus be an interesting scenario, but this is not considered likely. Moreover, the age of the household is only known in rather wide age categories, which make scenario studies more difficult.

In Table 25 an overview of the four scenarios is provided. In this table the adaptions compared to the reference sample are presented. The reference sample is the weighted TNS NIPO sample. The reference sample (N=1549) includes only people of which the municipality is known and does not include people who are participating in other forms of carsharing than round-trip carsharing. The sample is thus exactly the same as the sample used for estimation. Weights (as determined in Appendix J) are applied in order to make the choice-based sample representative for the complete population. The weights solely correct for the oversampling of carsharing participants and it is thus assumed that no other oversampling is present. It is however acknowledged that an oversampling of people living in highly urbanized regions (level 1) seems to be at present. In case of the fourth scenario, a smaller sample is used (N=1230): all people of which the household income is unknown, are eliminated. It is assumed that these households are randomly distributed over the sample and therefore the same weighting factors are applied as for the larger sample. It should however be noted that as a result, the weighted sample size reduced from 1230 to 1221. There are thus slightly more carsharing participants among the households that did not provide information on their household income.

TABLE 25: ADAPTIONS IN SCENARIO SAMPLES COMPARED TO REFERENCE SAMPLE. ALL VARIABLES THAT ARE NOT MENTIONED REMAINED UNCHANGED.

#	Scenario	Distribution in weighted reference sample	Distribution in scenario sample
1	Increased awareness	80.1% of the households aware of carsharing	100% aware of carsharing
2	Increased awareness and increased popularity in social environment	80.1% of the households aware of carsharing 17.3% of the households have carsharing participants in their social environment	100% aware of carsharing 100% has carsharing participants in social environment
3	Urbanization of municipalities	32.6% Level 1 26.3% Level 2 18.5% Level 3 14.7% Level 4 7.7% Level 5	59.0% Level 1 18.5% Level 2 14.7% Level 3 7.7% Level 4
4A	Increased financial prosperity +10%	Mean gross household income: €48,661	Mean gross household income: €53,528
4B	Increased financial prosperity +20%	Mean gross household income: €48,661	Mean gross household income: €58,393

6.2 Model application results

Table 26 presents the results of the scenario studies. In the table, the distribution of the households over the five alternatives is shown: no car and no carsharing participation (0n); 1 car and no carsharing participation (1n); 2 or more cars and no carsharing participation (2+n); no car and carsharing participation (0rt); and 1 or more cars and carsharing participation (1+rt). Moreover, the table shows the percentage of households opting for one of the two round-trip carsharing alternatives (%CS) and an estimation of the total number of cars (# cars). To calculate the number of cars, the average number of cars for the 2+n and 1+rt alternative are assumed to be respectively 2.138 and 1.373. These numbers are based on the averages in the reference sample.

The results show that the largest change in carsharing participation can be expected when every household knows somebody in their social environment who is participating in carsharing. In the other scenarios, the carsharing participation will grow, but in absolute numbers the usage will still be marginal. The biggest reduction in the total number of cars is achieved via urbanization. Below, each of the scenarios is discussed in more detail.

TABLE 26: SCENARIO STUDY RESULTS

	0n	1n	2+n	0rt	1+rt	% CS	# cars
Reference scenario (N=1549)	217.2	913.9	398.9	12.8	6.1	1.2%	1775
Scenario 1 – Awareness	**216.8**	**912.9**	**398.4**	**14.1**	**6.8**	**1.3%**	**1774**
Absolute deviation from reference	*-0.4*	*-1.0*	*-0.5*	*+1.3*	*+0.7*		*-1*
Relative deviation from reference	*-0.2%*	*-0.1%*	*-0.1%*	*+10.2%*	*+11.5%*		*-0.1%*
Scenario 2 – Social environment	**206.9**	**877.8**	**381.3**	**53.2**	**29.9**	**5.3%**	**1734**
Absolute deviation from reference	*-10.3*	*-36.1*	*-17.6*	*+40.4*	*+23.8*		*-41*
Relative deviation from reference	*-4.7%*	*-4.0%*	*-4.4%*	*+315.6%*	*+390.2%*		*-2.3%*
Scenario 3 – Urbanization	**240.2**	**955.8**	**331.4**	**15.5**	**6.1**	**1.4%**	**1672**
Absolute deviation from reference	*+23.0*	*+41.9*	*-67.5*	*+2.7*	*+0.0*		*-103*
Relative deviation from reference	*+10.6%*	*+4.6%*	*-16.9%*	*+21.1%*	*0.0%*		*-5.8%*
Reference scenario (N=1221)	179.3	735.3	290.0	11.1	5.3	1.3%	1363
Scenario 4A – Household income raise +10%	**169.1**	**727.2**	**307.9**	**11.3**	**5.5**	**1.4%**	**1393**
Absolute deviation from reference	*-10.2*	*-8.1*	*+17.9*	*+0.2*	*+0.2*		*+30*
Relative deviation from reference	*-5.7%*	*-1.1%*	*+6.2%*	*+1.8%*	*+3.8%*		*+2.2%*
Scenario 4B – Household income raise +20%	**159.7**	**718.4**	**352.9**	**11.4**	**5.7**	**1.4%**	**1481**
Absolute deviation from reference	*-19.6*	*-16.9*	*+62.9*	*+0.3*	*+0.4*		*+118*
Relative deviation from reference	*-10.9%*	*-2.3%*	*+21.7%*	*+2.7%*	*+7.5%*		*+8.7%*

In the first scenario, in which the awareness is raised with almost 25% (from 80.1% to 100%), the actual carsharing participation is only found to grow with 10.6%. The households that are unaware of carsharing are thus also less likely to participate in round-trip carsharing when they would have known about it. The limited effect is not unexpected: households who are not aware of carsharing, live more often in rural areas, where carsharing is not available, and are thus also less likely to know people in their social environment that are participating in a carsharing program. There are thus other, correlating, variables that make these household less likely to become a carsharing participant. It is however expected that in reality an increased awareness will have a larger impact. In Scenario 1, only a change from 'unknown' to 'known' is measured, but in practice there are various gradations of awareness. Literature study for example showed that many people are known with carsharing but have a poor perception of the actual service levels (SmartAgent, 2011).

The second scenario, in which everybody is aware of carsharing and knows people in their social environment participating in carsharing, shows a much larger potential for carsharing. An increase in awareness (+25%) and a large increase in carsharing participants in the social environment (+578%), is expected to result in an overall growth of 340% in carsharing participants. The results of the second scenario imply that a snowball-effect in round-trip carsharing participation can be expected: more carsharing participants lead to more households who know of carsharing participants in their social environment, which leads to more carsharing participants. However, the scenario also shows that there is a maximum: when everybody knows of carsharing participants in their social environment, around 5.3% of the households will participate in round-trip carsharing programs. It is questioned whether the maximum is reached: if 5.3% of the households are participating in carsharing, there might still be social environments in which no carsharing participants are present.

The third scenario, an extreme scenario in which all municipalities become more urbanized, shows that population density on its own will only have a limited impact on carsharing participation. The percentage of carsharing participants will rise with 14.3% from 1.22% to 1.39%. More interesting is the effect on car ownership. As a result of the extreme urbanization, car ownership is estimated to reduce with almost 6%. It should however be emphasized that this scenario was designed with the aim to explore the growth boundaries of carsharing participation. Therefore, extreme scenarios are designed, which are not per definition plausible. In reality, urbanization will lead to an increased household density in already urbanized regions, but will also come along with a reduced household density in rural areas. In those areas, the car ownership is expected to increase.

The final scenario shows the impact of an increased financial prosperity. The results show that an increased income (of either 10% or 20%) will only have a marginal effect on the car sharing participation, but does impact the car ownership. As a result of an increased household income, the number of households with 2 or more cars is rapidly growing.

In order to better compare the impact of the altered variables, Table 27 shows the relative impacts of the first, second and fourth scenario. The third scenario is not represented in the table, because the urbanization degree is an ordinal measurement and the adaption could thus not be expressed in an actual growth percentage in household density. To measure the effect of carsharing participants in the social environment, scenario 2 is compared to scenario 1. The table shows that a change in the social environment has a stronger effect on carsharing participation than a change in the awareness.

TABLE 27: RELATIVE IMPACTS OF THE VARIOUS SCENARIOS ON ROUND-TRIP CARSHARING PARTICIPATION

		Effect on round-trip carsharing
1	Increase of 1% in awareness in the population	+0.42%
2	Increase of 1% in carsharing participants in social environment	+0.62% (compared to Scenario 1)
4A	Increase of 1% in household income	+0.24%
4B	Increase of 1% in household income	+0.21%

6.3 Conclusion

The aim of this chapter was to determine how carsharing participation might change under various future scenarios. To do so, four different scenarios are tested: (1) Increased carsharing awareness, (2) Increased carsharing awareness and increased carsharing participation in social environment, (3) Urbanization, and (4) Increased prosperity.

Based on the model application results, it is concluded that increased carsharing awareness, urbanization or increased financial prosperity will have a limited effect on carsharing participation. Increased carsharing participation in the social environment is however found to have the potential to significantly change the carsharing participation in the population. When everybody in the population is aware of carsharing and knows someone in their social environment that participates in carsharing, round-trip carsharing participation is expected to increase from 1.2% to 5.4% of the population.

CHAPTER 7

7 CARSHARING PARTICIPATION AND CAR OWNERSHIP MODELLING IN THE LMS

In this chapter an empirical model is constructed that is attuned to the LMS model. The design of such an empirical model helps to determine to what extent the LMS model structure and the population data available in the LMS are sufficient for the modelling of carsharing participation.

This chapter starts with a general introduction on the LMS model and a description on how car ownership is currently modelled in the LMS model. Next, the position of the new carsharing and car ownership module in the LMS model is determined and required adaptions to the LMS are discussed. Then, an empirical model is estimated that takes into account the population data that is available in the LMS model. Next, a comparison is made with the 'best possible model' and the conceptual model. The chapter concludes with a presentation of the major findings.

7.1 INTRODUCTION TO THE LMS

LMS is short for 'Landelijk Model Systeem', which freely translates to 'National Model System'. The LMS is a tour-based strategic travel demand model for passenger transport that is managed by the Rijkswaterstaat. The LMS models the travel demand on the main road- and rail network in the Netherlands and consists of ±1.600 zones and ±74.000 road links. When a higher level of detail in the transport network is demanded, one of the four different regional models are used (NRM). The LMS model enables the Rijkswaterstaat to make forecasts on the future travel demand and to estimate the expected effect of transport policies.

The operation of the LMS is simplified and schematized in Figure 18. The LMS is a static forecast model that determines the future year matrices with a pivot point method[16]. The travel demand model within the LMS requires input on the population, network accessibility and foreign traffic of both the base year and the future year. This information is currently determined in three separate modules: The population module, the accessibility module and the foreign traffic module. Moreover, base year matrices are required, which are synthetic matrices that are based on travel surveys and calibrated via traffic counts. For a thorough explanation on the operation of the LMS model, it is referred to the technical documentation (Rijkswaterstaat, 2017). In the remaining part of this paragraph, it is focused on the specific parts in which car ownership modelling play a role.

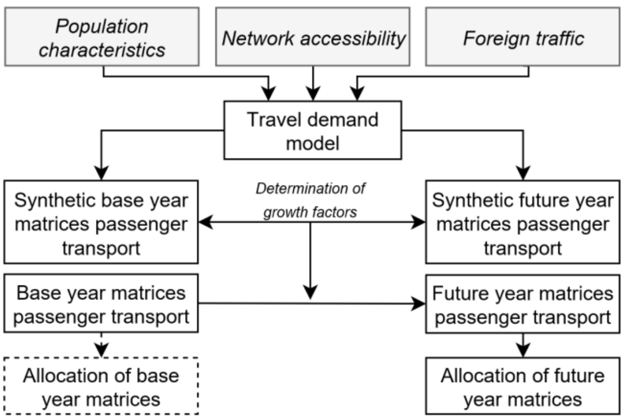

FIGURE 17: SIMPLIFIED REPRESENTATION OF THE OPERATION OF THE LMS MODEL

[16] Pivot point method: Synthetic matrices for both the base year and the future year are formulated via a travel demand model. Next, growth factors between the synthetic matrices are calculated and then applied to the base year matrices in order to determine the future year matrices for passenger transport.

7.1.1 Current car ownership modelling in the LMS

In the preparations of the travel demand model, a car ownership model is applied that models the number of cars per household. In the travel demand model, the household's car ownership influences the trip frequency, mode choice, trip destination and time of day choice.

The car ownership model needs some explanation, because its parameters differ between the run for the base year and the future year. The parameters of the car ownership model are mostly estimated outside the LMS by Significance (Willigers, et al., 2017), but the alternative specific constants in the utility functions are adapted to meet zonal and national targets, see also Figure 18. The initial car ownership model is an MNL model that distinguishes four alternatives: 0, 1, 2 or 3+ cars. The variables that are included in this model are earlier discussed in paragraph 3.2.2: Explaining variables in car ownership models and also attached in Appendix P.

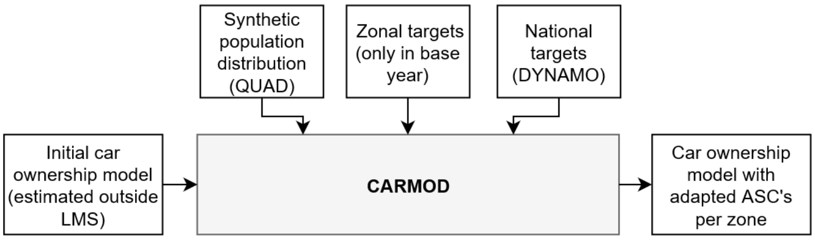

FIGURE 18: DETERMINATION OF CAR OWNERSHIP MODEL FOR APPLICATION IN THE LMS

The program structure of CARMOD is presented in Figure 19. In CARMOD, the initial car ownership model is applied on a synthetic household distribution, which is determined in an earlier program of the population module: QUAD. QUAD basically produces a synthetic population distribution for both the base year and the future year, by determining multiplication factors for the households questioned in the national travel survey[17]. After the first model application, the ASC's are iteratively corrected, such that the national totals are consistent with the total car fleet, as determined in DYNAMO. DYNAMO (dynamic automobile market model) is an external model that determines the developments in the national car fleet per year (MuConsult B.V., 2015). The DYNAMO output that is used in CARMOD, includes the total number of households with 0, 1, 2, or 3+ cars in The Netherlands for both the base year and the future year. In the base year, an extra iteration is present that makes the zonal totals consistent with the total car fleet per zone via zonal multiplication factors.

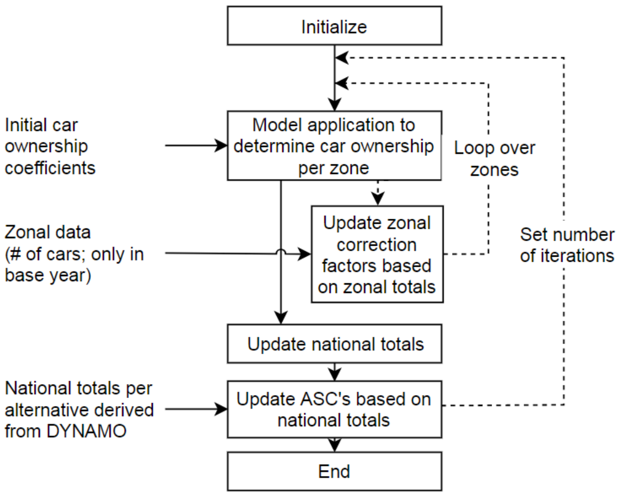

FIGURE 19: PROGRAM STRUCTURE OF CARMOD. ADAPTED FROM (RIJKSWATERSTAAT, 2017, P. 181)

[17] The national travel survey that is used in the latest LMS model is the MON of 2007-2009. In total 311 household categories can be distinguished, based on household composition, number of children, number of employers, driving licence possession, and age, gender and employment of the head of the household.

7.2 Position of car ownership and carsharing participation model in the LMS

Figure 20 shows the position of the car ownership and carsharing participation model in the LMS. The new (externally estimated) model thus replaces the former initial car ownership model and functions as input for the CARMOD program. As a result, adaptions are needed to CARMOD and in later steps of the LMS model. Below, the required adaptions to (the input of) CARMOD are addressed, where after an inventory is made of the required adaptions the travel demand models in general and the LMS in specific.

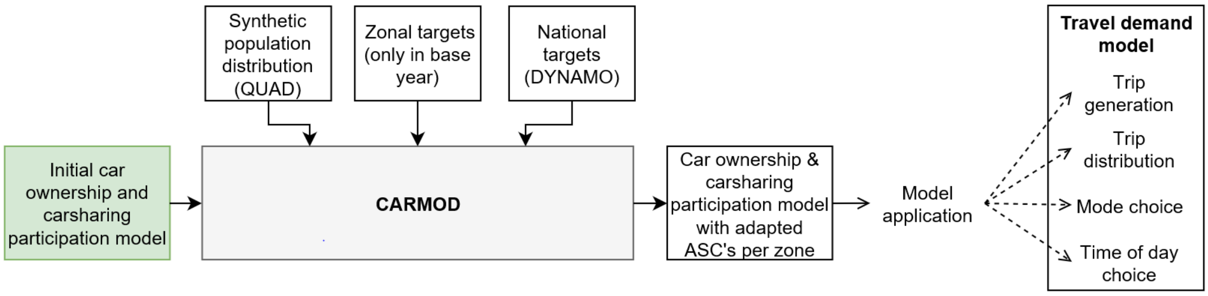

FIGURE 20: POSITION OF CAR OWNERSHIP AND CARSHARING PARTICIPATION MODEL (DENOTED IN GREEN) IN LMS.

7.2.1 Adaptions related to CARMOD

CARMOD adapts the ASC's of the initial model in order to match the (zonal- and) national totals. To do so, CARMOD applies the initial model on the synthetic household distribution (which is a multiplication of the population sample) for either the base year or the future year. The population sample should thus contain information on all variables that are specified in the initial car ownership and carsharing participation model. During this study, the variable specification of the initial model is tuned towards the presence of variables in the population sample, which is further discussed in paragraph 7.3.1. On the longer term, the estimation sample (TNS NIPO) or the population sample could be adapted to account for a larger set of variables. Recommendations for these adaptions are discussed in chapter 7.4.

For the ASC correction, CARMOD uses the zonal targets for the total number of cars (only for the base year) and the national totals for each alternative as determined via DYNAMO. The zonal targets for the CARMOD model currently only include the total number of cars for each zone in the base year. Ideally one would also have measures on the total number of households participating in round-trip carsharing per zone, since it is expected that zonal differences are present that are not caught in the model. If this information is not available, one could decide to only correct for the total number of cars in the zone.

For the national totals in both the base year and the future year, output of DYNAMO is used. In DYNAMO the total car fleet is modelled, just as the total number of households with 0, 1, 2 or 3+ cars. Currently DYNAMO does not take into account round-trip carsharing participation, and changes in the car ownership due to changing carsharing participation are thus not accounted for. One could deal with this issue in two ways: (1) adapt the DYNAMO model or (2) correct the output of the DYNAMO model afterwards. For now, the adaption or correction of the DYNAMO output is not further studied, but it is addressed that it is needed before carsharing can be implemented in the LMS. In Appendix Q, a conceptual model for a carsharing supply and demand model is attached that can be used as a basis for future studies.

7.2.2 Adaptions to strategic travel demand models in general

In order to account for carsharing in strategic travel demand models, various solutions can be thought of and therefore future studies are needed. Below, recommendations are given for possible solutions based on the author's insights, but it should be emphasized that other solutions might turn out better after a thorough study.

The first recommendation is the **addition of an extra mode**: round-trip carsharing. On the moment, travel demand models mostly distinguish the car driver, the car passenger and one or more public transport modes.

Some models (among which the LMS) also account for cycling and walking. Currently, carsharing is thus not distinguished as a separate mode. However, looking at carsharing and car ownership, we have seen that both travel time as travel costs differ significantly. The travel time is affected by access- and egress times for carsharing and the cost structure of both alternatives are found to be completely different. Given the fact that utilities are strongly affected by travel time and travel costs, carsharing is thus preferably modelled as a separate mode. As part of the addition of the new mode, utilities have to be determined for all possible tours that can be made via shared car. The determination of these utilities is left for future research.

Moreover, future studies are needed to determine whether adaptions should be made on **travel frequency and trip destination**. In the current LMS model, the person's car availability (as a function of the number of cars in a household and the number of driving licence holders) is found to affect the travel frequency and trip destination. It is expected that also carsharing participation will have an effect on the travel frequency and destination choice and therefore additional research is needed.

In the specific case of the LMS (and in all other strategic travel demand models that make use of a pivot point method) also **adaptions are needed in the application of the growth factors**. As a result of the addition of a new mode, the model will calculate growth factors for the trips made by round-trip shared car. To determine the future year matrices, these growth factors are applied to the base year matrices. The base year matrices however do not include information on shared car usage and this is also hard to implement, because automatic traffic counts cannot make a distinction between shared cars and private cars. Therefore, it is recommended to sum the private- and shared car trips in the synthetic matrices and to determine a combined growth factor.

7.3 Empirical model estimation for LMS

In this paragraph the model specification of the best possible model for car ownership and carsharing participation is attuned to the data available in the LMS. From now on, this model will be referred to as the 'LMS best possible model'. For the estimation of the model, the TNS NIPO sample is used. Hence, only variables can be used that are present in both the TNS NIPO sample and the population sample that is used for the LMS. The LMS best possible model is thus a simplified version of the best possible model designed in chapter 5.

In this paragraph, first the variables are selected that can be used for the LMS best possible model. Next, the model estimations results are presented and discussed.

7.3.1 Variable selection for the empirical model for LMS

The LMS best possible model can only contain variables that are present in both the estimation sample and the LMS data of both the base- and the future year, see also Figure 21. The data that is available for both years, is a combination of a synthetic population distribution and additional information. The synthetic population is basically a multiplication of the population sample based on socio-demographic targets on a national or zonal level (such as the number of students in the country or the number of employees in a municipality), and thus contains data on all questions that are asked for in the population sample. The additional data that is used in the base- and future year is either observed or estimated and can be matched to the household in the synthetic population sample via location, year and/or household type. Examples are the parking tariffs, the accessibility of a zone, and the cost index.

In order for the carsharing participation and car ownership model to be incorporated in the LMS environment, the variable specification of the model should match the variables that are present in the LMS data. Below, it is therefore explored to what extent the variables used in the best possible model are present in LMS environment. To do so, various population samples are consulted, because the population sample that is conducted towards travel behaviour in The Netherlands differs over the years.

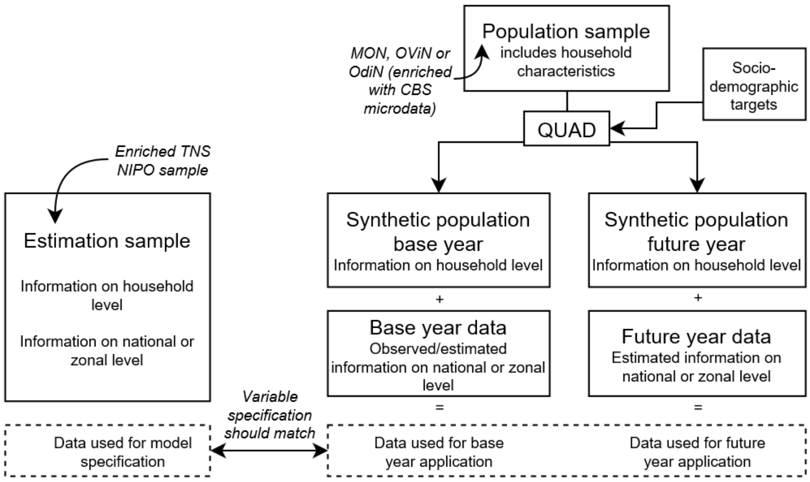

FIGURE 21: REQUIREMENTS FOR VARIABLE SPECIFICATION OF LMS BEST POSSIBLE MODEL

The population sample that is used in the latest LMS version is the MON[18], which holds data for the years 2004-2009. The successor of the MON is the OViN[19], which is conducted yearly in the period of 2010-2017. From 2018 onwards, a new questionnaire will be used, called the ODiN[20]. In contrast to the OViN and the ODiN, the MON survey asked for various household characteristics. To determine the household characteristics of the respondents in OViN and ODiN, CBS microdata can be linked on a variety of topics. Table 28 shows which variables of the 'best possible model' are present in the MON survey and the CBS microdata. It is however still questionable whether the OViN or ODiN will be used for the next LMS version. Therefore, also the population sample that is collected by the KiM is included in the overview. The MPN[21] is much smaller (ca. 2,000 households) and contains data over several years, in order to observe changes in mobility behaviour. For the travel surveys that are conducted by the CBS, each year information is gathered on more than 30,000 (new) respondents.

TABLE 28: VARIABLES IN THE BEST POSSIBLE MODEL AND THEIR PRESENCE IN POPULATION SAMPLES ON HOUSEHOLD LEVEL

Variables used in the best possible model	Available in MON	Available in CBS microdata	Available in MPN
Awareness of carsharing	-	-	-
Dummy: living in Amsterdam	x	x	x
Number of adults in the household	x	x	x
Number of children in the household	x	x	x
Age	x	x	x
Income	x	x	x
Education	x	x	x
Dummy: Carsharing participants in social environment	-	-	-
Urbanization degree	x	x	x

As can be seen in Table 28, in all population samples the municipality, number of adults, number of children, age, income, education, and the urbanization degree is known on household level. Regardless of the exact sample that will be used for the next LMS version, it can thus be assumed that this information will be available. It should be noted that the specifications of the variables vary slightly: the age categories differ and the income is for example in the CBS surveys collected as disposable household income, while the MPN uses the gross household income.

[18] MON (CBS): Mobiliteits Onderzoek Nederland [Mobility Survey Netherlands]
[19] OviN (CBS): Onderzoek Verplaatsingen in Nederland [Survey Movements in The Netherland]
[20] ODiN (CBS): Onderzoek Onderweg in Nederland [Survey On the go in The Netherlands]
[21] MPN (KiM): Mobiliteits Panel Nederland [Mobility Panel Netherlands]

At the same time, in neither of the surveys information is available on the carsharing awareness or the presence of carsharing participants in the social environment. Because this information is household specific, it can also not available in the additional information for the base- and future year. Hence, the model specification for the LMS best possible model should be adapted: everybody should thus be faced with the full set of alternatives and no parameters can be estimated for the presence of carsharing participants in the social environment.

7.3.2 Empirical model results of car ownership and carsharing participation model for LMS

Table 29 presents the model results of the LMS best possible model. For the estimation of the model, again an MNL modelling approach is used in which five alternatives are distinguished: no car and no carsharing participation (0n); 1 car and no carsharing participation (1n); 2 or more cars and no carsharing participation (2+n); no car and carsharing participation (0rt); and 1 or more cars and carsharing participation (1+rt). The model is estimated based on the TNS NIPO sample that is also used for all earlier estimations. In contrast to earlier estimations, this time everybody is faced with the full set of alternatives, because in the synthetic population no data is available on the household's carsharing awareness.

Estimation results are in line with hypotheses and earlier estimation results, apart from the negative sign for the parameter that quantifies the effect of the number of adults in the household for the 0rt alternative. Although the parameter is not significant, the negative sign is still unexpected, because car travel demand (and thus willingness to participate in carsharing) is expected to increase when more adults are present in the household.

TABLE 29: LMS BEST POSSIBLE MODEL (N=1549 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). MNL MODEL. RESPONDENTS OF WHICH MUNICIPALITY IS UNKNOWN ARE EXCLUDED. REFERENCE: 0N (NO ROUNDTRIP CARSHARING, NO CAR). SIGNIFICANT PARAMETERS (P<0.05, T-STATISTIC >1.96) ARE MARKED IN BOLD. ALL RESPONDENTS WERE FACED WITH THE FULL SET OF ALTERNATIVES.

Number of observations	1549
Final log likelihood	-1545.2
Degrees of Freedom	33
Rho²(0)	0.380

	0n		1n		2+n		0rt		1+rt	
ASC*			**1.760**		**-2.308**		**-5.028***		**-7.850***	
Dummy: living in Amsterdam	**0.847**	*4.1*								
Number of adults in the household			**0.353**	*2.4*	**1.244**	*7.6*	-0.209	*-0.9*	**1.303**	*5.2*
Number of children in the household			**0.966**	*4.5*	**1.059**	*4.9*	**0.529**	*2.0*	**1.252**	*5.2*
Dummy: Age partner breadwinner <40			**-1.520**	*-7.8*						
Dummy: Age partner breadwinner 40-49			**-1.010**	*-4.6*						
Dummy: Age partner breadwinner 50-64			**-0.606**	*-3.2*						
Dummy: Age partner breadwinner 40-64					0.309	*1.7*				
Dummy: Age partner breadwinner <64							**0.931**	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.187**	*4.5*	**3.969**	*7.6*	**3.025**	*5.3*	**3.343**	*5.3*
Dummy: income unknown			**0.953**	*3.3*	**2.198**	*6.7*	**0.935**	*2.3*	**1.195**	*2.1*
Dummy: HBO+ education									**1.388**	*3.9*
Dummy: Urbanization degree 1			**-1.307**	*-4.3*	**-2.544**	*-7.5*			**-0.719**	*-2.0*
Dummy: Urbanization degree 1 and 2							**1.116**	*2.9*		
Dummy: Urbanization degree 2 and 3			**-0.707**	*-2.6*	**-1.270**	*-4.4*				
Ref: Urbanization degree 4 and 5										

*The ASC's are calibrated to account for the oversampling of carsharing users.

7.4 Comparison with the 'best possible model'

Looking to the modelling results of the 'LMS best possible model' and comparing them with the results of the 'best possible model' (Table 24, page 57), one can see that most parameters have more or less the same value. At the same time, a number of differences catch the eye.

First of all, the model fit of the LMS best possible model is clearly lower. In comparison: the earlier best possible model has a log likelihood of -1418.5 and a ρ^2 of 0.398. The difference in log likelihood thus equals 126.7 points, while the best possible model only has two additional degrees of freedom. The elimination of the two parameters (in the carsharing alternatives for the presence of carsharing participants in the environment) is however not the only cause of the drop in model fit. The model structure is also adapted: people unaware of carsharing are in the LMS best possible model faced with the full set of alternatives, while in the best possible model these people are only faced with the alternatives that do not include carsharing participation.

Second, it can be seen that the sign of the (insignificant) parameter for the number of adults in the 0rt alternative switches. Also for the 1+rt alternative the parameter for the number of adults is found to have lowered. Based on these results, one can conclude that households with fewer adults are more often aware of carsharing[22] and/or know more often of people in their social environment that participate in carsharing[23]. This is counterintuitive, since one would expect that the carsharing awareness or the presence of carsharing participants in the social environment would rise when more adults are present in the household. A possible explanation can be found in the fact that people living in single households are often younger and younger people are on their turn better aware of the latest developments. Moreover, people in single households are more often carsharing participants and it can be expected that these people interact more with other people living in small households.

Last, it is found that the parameter for the age of 40-64 in the 2+n alternative is no longer significant within the 95% confidence interval, although still a positive value can be observed of around the same magnitude.

Due to the differences between the earlier best possible model and the LMS best possible model, the latter one will give less accurate results in model applications. Moreover, in future year applications, the LMS best possible model does not account for changes in carsharing awareness or presence of carsharing participants in the social environment. This is considered a major shortcoming due to two reasons: (1) the two variables are expected to change (considerably) towards the future and (2) changes in the presence of carsharing participants in the social environment are found to have a rather large effect on the carsharing participation compared to other variables such as income or urbanization (see also scenario studies, Chapter 6).

At the same time, as a result of the rather similar parameter values for the remaining variables, the LMS best possible model will give similar application results (compared to the earlier best possible model) when testing for effects such as urbanization, ageing or increased financial prosperity. Only scenarios that test for the effect of individualization might be somewhat of, due to the negative parameter for the number of adults in the '0rt' alternative.

7.5 Comparison with the conceptual model

Based on the estimation results, it can be concluded that both the estimation sample (of TNS NIPO) and the set of variables that is available in the LMS have limited the operationalization of the conceptual model in a best possible empirical model. This affected both the model structure and the explaining variables that are specified in the utility functions.

The aim of this paragraph is to assess the differences with the conceptual model and to provide recommendations on how the empirical model for car ownership and carsharing participation could be improved (meaning more closely represent the conceptual model) for incorporation in the LMS. To do so, first

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[22] In the earlier best possible model, the parameters of the round-trip carsharing alternatives were only estimated based on observations of people aware of carsharing (because people unaware of carsharing were only faced a limited set of alternatives). Hence, a positive parameter thus indicated that a specific characteristic was more often present in a certain alternative compared to other households aware of carsharing. In the LMS best possible model, everybody is faced the full set of alternatives and parameters thus represent differences compared to any other household.

[23] The positive effect of the number of adults was found, given that people have carsharing participants in their social environment. In the LMS best possible model, this latter variable is no longer included. If people unaware of carsharing are more often living in larger households; now a negative parameter might show.

the compromises are addressed and explained, that were made in the operationalization of the conceptual model into an empirical model for the LMS. Next, opportunities for improvement are provided.

In this paragraph two different samples are referred to. The term 'population sample' refers to the national travel behaviour questionnaires (i.e. OViN and ODiN) that are used to determine the synthetic population distribution in the LMS model on which the carsharing participation and car ownership model is applied. The term 'estimation sample' refers to the sample that is used for the estimation of the empirical model. In this case the TNS NIPO sample.

7.5.1 Compromises made in the specification of the LMS best possible model

Table 30 provides an overview on the compromises that had to be made in the specification of the modelling approach, the choice set, and the utility functions. In an additional column, the reason for the compromise is provided. As can be seen, the majority of the compromises has to do with the specification of the utility function, since the conceptual model contained far more hypothesized explaining variables than represented in the LMS best possible model. Moreover, the table shows that most of the compromises are a result of the estimation sample, be it the size, quality, content or data collection method. In two cases, the absence of variables in the LMS model has led to compromises.

TABLE 30: OVERVIEW OF COMPROMISES THAT HAD TO BE MADE IN THE OPERATIONALIZATION OF THE CONCEPTUAL MODEL

Category	*Compromise*	*Reason*
Model approach	Specification of an MNL model rather than a model that accounts for unobserved correlations in the utilities between the alternatives	Choice-based estimation sample.
Choice set	People unaware of carsharing are also faced with the carsharing alternatives, while in reality these alternatives will not be considered.	Carsharing awareness not known in synthetic population in the LMS model.
	Car ownership could only be determined up to 2+ cars; and in case of combination with carsharing participation only up to 1+ cars, while one would ideally model up to 3+ cars.	Too few observations in the estimation sample.
Utility function	The empirical model holds less household characteristics than shown in the conceptual model.	Variables are missing in the estimation sample.
	The empirical model holds less land-use characteristics than shown in the conceptual model.	Observations are missing in the estimation sample and could not be added via data enrichment.
		Data enrichment was only possible on the municipality level, which is too aggregated for numerous variables.
		Variable is missing in the data for the base/future year and could not be added via data enrichment.
		Too few observations. Effects of correlating variables could hardly be told apart.
	The empirical model does not account for the impact of alternative specific characteristics such as costs, access time and availability.	Observations are missing in the estimation sample.
	The LMS best possible model does not account for the impact of carsharing participants in the social environment.	Variable is missing in the data for the base/future year and could not be added via data enrichment.
	The empirical model does not take into account travel behaviour related characteristics.	Variables are not available on a household level in the estimation sample.
	Very few differentiation in age and urbanization degree in the round-trip carsharing alternatives	Too few observations in the estimation sample.
	A dummy variable for Amsterdam had to be included.	Estimation sample poorly representative for the population in terms of spatial distribution.

7.5.2 Opportunities for improvement of the LMS best possible model

All compromises as presented in Table 30 are directly or indirectly a result of data availability, either in the LMS environment or in the estimation sample. Solutions can be found in adapting the data collection method and by collecting data on a larger set of variables.

Below, first the data collection of the estimation sample is discussed. Next, it is reviewed how information could be collected on the variables that could not be tested in this thesis, but are still hypothesized to affect carsharing participation and/or car ownership.

Data collection method

In the case study, a choice-based sample is used, which hindered the comparison of various modelling approaches in the empirical modelling. To be able to study other modelling approaches, it might thus seem attractive to collect a random sample instead. However, at the same time, it was found that the current number of carsharing observations is already low, in spite of the oversampling. By way of comparison: in order to collect the same number of carsharing observations in a random sample, around 12,400 observations are needed assuming the round-trip carsharing participation rates that were found for The Netherlands in 2014 (de Gier, et al., 2014). However, a solution can be thought of: using the population sample as an estimation sample. The population sample in the Netherlands counts over 30,000 responses and is collected on a yearly base. An additional benefit of using the national travel survey, is that information is available on travel behaviour. To be able to use this sample for estimation purposes, the survey should be extended with a question on the carsharing participation of the household.

Data collection of missing variables

Table 31 shows all variables that are present in the conceptual model. For each variable it is noted to what extent information is available in the LMS in the base year and the future year (both the synthetic population distribution and the additional data). No separate column is included for the estimation sample, because it is assumed that the (enriched) population sample will be used for estimation purposes. It should be noted that the recommendations on how to collect the missing variables are merely suggestions. Further studies are needed to determine whether this is the best way to collect the data.

As can be seen in the table, the land-use variables can mainly be derived from external data sources. Linkage of external data sources should be done on the smallest possible scale, since the case study showed that linkage of external sources on the municipality level was not successful, due to large variation within the municipality. Two of the land-use variables are not available: the availability of parking spots and the average access time to the private car. The variables are poorly measurable because the definition of a parking spot is rather broad. For some land-use variables, it can be seen that future targets are needed. In case of parking permits, future targets can be set based on expected area development. Future targets for the shared car supply in terms of access time and density are however more complicated. This completely depends on developments in the carsharing market, which are a result of the demand, carsharing regulations of the municipality, and the willingness of organizations to offer shared cars in the specific area. It can be thought of a separate supply and demand model, but due to uncertain developments, in these cases scenarios might be better suitable, meaning that multiple future targets are set to measure the impact of various plausible scenarios.

Among the household variables, the table shows that all desired information is currently available in the population sample and thus available for the base- and the future year. In contrast to the TNS NIPO sample, in this case thus also information is available on gender, employment and driving licence possession. Moreover, the age is for all observations available on a household level (head of the household).

Regarding the remaining variables, some additional remarks should be made. As can be seen, only for the car travel demand, future targets are available, which can be derived from DYNAMO. In DYNAMO an estimation of the car travel demand is made for 128 different household types that can be told apart based on the household size, number of working people, age of the oldest person in the household, and the disposable household income. In order to link the car travel demand, all this information should thus also be collected in the population sample. During this thesis it was not possible to link the car travel demand, because only the household size was known. Age and income were measured in a different way (age of partner of breadwinner and gross household income) and employment was not available at all. DYNAMO however only produces a car travel demand in terms of yearly mileage. To determine the cost difference between carsharing and car ownership, also a time component is needed. For the base year, it is recommended to derive averages for each household type via the national travel demand surveys. For the future year, targets or scenarios are needed.

TABLE 31: POTENTIAL PRESENCE OF DATA ON THE VARIABLES OF THE CONCEPTUAL MODEL

Hypothesized influencing characteristic	Base year	Future year	Source:
Land-use variables			
Distance to work/facilities	+	+	**Proxy:** urbanization degree on municipality level. Derived from Zonal Targets.
Availability of parking spots in public area	-	-	
Average access time to parking spot	-	-	
Need for parking permit	+	Target needed	Can be collected in base year via information of municipalities. For future year targets are needed.
Car accessibility	+	+	Accessibility indicator for car transport on municipality level (BBI)
Public transport accessibility	+	+	Accessibility indicator for public transport (BBI-ov)
Distance to nearest shared car	+	Target needed	For base year publicly available, estimation or scenario needed for future year.
Number of shared cars within walking distance	+	Target needed	For base year publicly available, estimation or scenario needed for future year.
Household variables			
Household size	+	+	Population sample & QUAD
Education level (head of household)	+	+	Population sample & QUAD
Number of children	+	+	Population sample & QUAD
Number of working people in household	+	+	Population sample & QUAD
Household income	+	+	Population sample & QUAD
Number of adult males in household	+	+	Population sample & QUAD
Age (head of household)	+	+	Population sample & QUAD
Number of driving licence holders	+	+	Population sample & QUAD
Other			
Car travel demand	+	+	DYNAMO
Yearly cost difference between car ownership and carsharing participation	+/-	Target needed	Can be calculated based on travel demand. For future car costs index available. For carsharing estimations needed on cost development.
Availability of parking spots on private property	+	Target needed	Survey in base year. Future targets needed
Shared car availability	?	Target needed	For the base year ideally data from carsharing organizations is obtained. For future year scenarios are needed.
Psychological value attached to car ownership	+	-	Collect on a Likert scale for base year
Awareness of carsharing	+	Target needed	Add question to population sample in base year and usage of separate model for future year
Number of round-trip carsharing participants in social environment	+	Target needed	Add question to population sample in base year and usage of separate model for future year
Perceived carsharing service level	-	-	
Environmental concern	+	-	Collect on a Likert scale for base year
Information about carsharing in municipalities' communication means	+	-	Information available on municipality's website

Moreover, a remark should be made on the future targets for carsharing awareness and the presence of carsharing participants in the social environment. When large changes in those variables are expected towards the future year, the usage of targets for the QUAD module will likely lead to implausible future year populations. In those cases, an additional binary choice model is preferred that determines the carsharing awareness and the presence of carsharing participants in the social environment, based on land-use and household characteristics.

7.6 Conclusion

The aim of this chapter was to explore (1) how carsharing participation modelling could be incorporated in the LMS model and (2) to what extent the variables that are available in the LMS environment are sufficient for the modelling of carsharing participation. Below, the two questions are answered one after the other.

How could carsharing participation modelling be incorporated in the LMS model?

Carsharing participation can be incorporated in the LMS via a joint model for car ownership and carsharing participation, which replaces the current initial car ownership model that is feed into the CARMOD program. The CARMOD program than calibrates the ASC's to meet national and zonal targets. In order for the LMS model to actually account for carsharing, some adaptions must be made to both the (input of the) CARMOD program:

- Zonal targets are preferably set on carsharing participation in the base year. If such information could not be collected, one could decide to only correct for zonal differences in the car ownership.
- National targets for the total car fleet in the future year as determined via DYNAMO should be adapted to account for the effects of carsharing participation, since an increase in carsharing participation is expected to lower (the growth of) the total car fleet.
- Preferably also national targets for carsharing participation in the future are set. This is however not a strict requirement: it can also be chosen to only correct the car ownership levels.

Knowing the carsharing participation of a household, this information can then be used in the travel demand model. It is expected that, apart from the mode choice, carsharing participation will also affect the trip frequency and trip destination. Further studies are needed to quantify these effects.

To what extent are the variables available in the LMS environment sufficient for the modelling of carsharing participation?

In order to answer this question, an empirical model is estimated that only takes into account variables that are present in the synthetic population distribution in both the base- and the future year. Due to the absence of a carsharing awareness variable, the model structure had to be adapted (all households are now faced the full set of alternatives, rather than only the people aware of carsharing) and moreover one of the explaining variables (presence of carsharing participants in social environment) had to be excluded from the model.

It can be concluded that these adaptions have significantly impact the model performance: the log likelihood dropped from -1418.5 to -1545.2 and the ρ^2 reduced from 0.398 to 0.380. Apart from the fact this will result in less accurate results in model applications, it is also expected that the model is even less accurate for future year applications because: (1) the two excluded variables are expected to change (considerably) towards the future and (2) changes in these variables are found to have a rather large effect on the carsharing participation compared to other variables currently included in the model. The conditions of the LMS environment thus limit the extent to which carsharing participation can be modelled, especially for future year applications.

It should be noted that in the LMS best possible model, only variables are included that are also present in the estimation sample (of TNS NIPO). However, with the help of a new estimation sample (preferably collected via adaptions to the national population sample), one could make use of some additional variables that are present in the LMS data: employment, gender and driving licence possession. Moreover, adaptions to the population sample might further improve the model fit of the car ownership and carsharing participation model. Hence, it is recommended that the ODiN survey is extended with the following information: age of the oldest person and disposable household income. In this way, it is possible to link the car travel demand of the household. Besides, information should be collected on the carsharing awareness and presence of carsharing participants in the social environment. Moreover, external data sources should be collected on the need for a parking permit in a certain area, the location of shared cars (and hence the access time and density) and preferably also the shared car availability, although for this latter variable collaboration with carsharing organizations is required.

CHAPTER 8

8 CONCLUSIONS & DISCUSSION

In this chapter the conclusions on the research questions are provided, where after the results are discussed.

8.1 CONCLUSIONS

At the start of this thesis, a research objective was formulated in the form of a design task:

1. Understand what factors affect carsharing participation by estimating choice models;
2. Specify how a joint model for carsharing participation and car ownership could be incorporated in the Dutch national transport model (LMS).

In the previous chapters various methods are used to the explaining variables of carsharing participation and to explore how such a model can be specified. Based on the findings in earlier chapters, in this chapter the answers are formulated on the sub questions, subsequently leading to the presentation of the final design: the specification of a joint model for carsharing participation and car ownership in the Dutch national transport model (LMS).

The sub questions that were formulated in the beginning of this research, read as follows:

1. What does the current carsharing market in The Netherlands look like and what developments can be expected in the nearby future?
2. What are the factors that affect someone's willingness to become a carsharing participant or to purchase a car?
3. How to jointly model car ownership and carsharing participation from a conceptual point of view?
4. To what extent can the conceptual model be operationalized into an empirical model with the data that is currently available?
5. What will be the impact of (potential) future developments on the total carsharing participation?
6. What are the possibilities to incorporate a joint model for carsharing participation and car ownership in the Dutch national transport model (LMS)?

8.1.1 ANSWERS TO THE SUB QUESTIONS

Below, each of the sub research questions will be answered one after the other.

1. "What does the current carsharing market in The Netherlands look like and what developments can be expected in the nearby future?"

It is first of all found that **there is no such thing as general carsharing**. In this thesis, it is decided to focus on business-to-consumer- (B2C) and peer-to-peer (P2P) carsharing, of which the first can be split into round-trip carsharing and one-way carsharing. In each of the three carsharing types, a **clear market leader** stands out: SnappCar is the major party for P2P-carsharing, Greenwheels is the main round-trip provider and Car2go is the clear leader on the one-way market.

Second, it is found that **the carsharing market (B2C & P2P) only accounts for a marginal part of the total car travel demand** in The Netherlands. The share of carsharing kilometres as part of all car kilometres driven in The Netherlands, is estimated on 0.03%. Based on an analysis of the supply and demand, it can moreover be concluded **that the supply of shared cars is a poor indicator of the actual usage of a specific carsharing type**. P2P-carsharing offers the largest supply (24,779 cars out of 27,605 shared cars in total), while round-trip cars are the most used (25 million out of 43 million kilometres driven per year by shared cars).

Moreover, it is concluded **that large variations exist among the carsharing types** in location, service levels, car types and cost structures. As a result of the variation in cost structures, the carsharing types **vary in trip characteristics**. One-way carsharing is mainly used for short distances, P2P carsharing is often used for trips that take more than a day and round-trip carsharing steers the middle course.

Towards the future, it is expected that **carsharing will grow**, albeit with car ownership retaining its importance. The **largest growth numbers are expected for one-way carsharing**. Moreover, organizations are expected to offer **varying carsharing types at the same time** and a **more varied fleet** with both electric and fuel driven cars. P2P carsharing is expected to become **more anonymous and more flexible** as a result of the **adoption of board computers and carsharing software in private cars**. Last, on the long term, it is expected that **development of automated guided vehicles** will have a severe impact on the carsharing market.

2. "What are the factors that affect someone's willingness to become a carsharing participant or to purchase a car?"

According to theory, the most important drivers to choose for carsharing participation rather than car ownership are **comfort** (carefree) and **costs**. **Environmental concern** is kept in the back of one's mind, but is not decisive. Moreover, poor **parking conditions** and **friends and family participating in carsharing** can motivate people to become a carsharing member. Reasons not to participate in carsharing, are the perceived **uncertainty** and **inflexibility** as a result of access times, limited availability, reservation obstacles and fixed time limits (the latter only for round-trip and P2P). In a cost comparison, it is found that **carsharing will lead to reduced costs up to a yearly mileage of circa 4000km**. In general, car travel demand showed a negative relation with carsharing participation in earlier studies.

Theory also showed that people who participate in carsharing are **higher educated** and **more environmentally conscious** than the average Dutchmen. Moreover, they earn **higher salaries**, are more often **living in single households** and are mostly **aged below 65**. Last, they are more likely to **live in highly urbanized regions**, with a **short distance to facilities**. Among P2P- and B2C carsharing participants, small differences are found: B2C carsharing participants live in more urbanized areas, receive higher incomes, live more often in single households and are higher educated than people participating in P2P carsharing. P2P carsharing participants are more often woman and living in households with children. Apart from demographics, carsharing participants are also found to vary from the general public in terms of mobility behaviour. Carsharing participants **make more trips, use the bike and public transport more often, and make less use of the car**. Moreover, people are found to adapt their mobility behaviour after becoming a participant: mainly **other cars and public transport are less often used**. Theory was not conclusive on the effect of **households with children**, and **income**, although it should be noted that the sources that found a positive relation, are considered more representative for the Dutch population.

Empirical research, which is merely focussed on round-trip carsharing participation, has confirmed the positive impact of the **presence of carsharing participants in the social environment** on round-trip carsharing participation. Households that do not own a car, but are participating in carsharing, are found to **live in more urbanized regions** and are **less often elderly** (>65), which is also shown in earlier studies. In contrast, households who combine car ownership with carsharing participation **less often live in highly urbanized areas** and are **not found to be overly represented in a specific age category**. Moreover, empirical analysis confirms the positive effect of higher education on carsharing participation, but only does so for people that combine carsharing with car ownership. No such relation is found for people who only use the shared car. Last, scenario studies showed that an increased **carsharing awareness** will lead to a higher number of carsharing participants. The empirical modelling results are mostly in line with previous work, although earlier studies did not make a distinction between carsharing participants that own a car and that do not.

Explaining variables for car ownership according to earlier modelling studies, include the following: **rural areas** (+), **distance to facilities** (+), **household size** (+), **household income** (+), **employment rate** (+), **driving licence possession** (+), **single household composition** (-), and **the share of female household members** (-). When the head of the household is **older** (up to 80 years) or **higher educated** chances of car ownership are found to increase. Moreover, car ownership increases when the household's **travel demand** is higher and **the distance to work** is longer. **High parking tariffs**, **public transport usage** and high **car ownership costs** lower the car ownership rates. Empirical analysis has confirmed the impact of household size, age, income, and rural areas. No effect is observed for higher education. Other hypothesized variables were not tested due to lacking data.

3. "How to jointly model car ownership and carsharing participation from a conceptual point of view?"

In the set-up of the conceptual model, it is concluded that **only round-trip carsharing** should be part of the joint model. Other carsharing types are excluded, because (1) P2P carsharing is expected to become more similar to round-trip carsharing towards the future and (2) one-way carsharing should not be modelled jointly with car ownership, but as an additional choice that depends on car ownership and participation in other types of carsharing. Furthermore, it is concluded that the joint modelling of car ownership and carsharing participation should be conducted on a **household level**, because the choice impacts the household budget and the car availability and transportation possibilities of all household members.

4. "To what extent can the conceptual model be operationalized into an empirical model with the data that is currently available?"

In this thesis, it is found that the conceptual model could only to a limited extent be operationalized into an empirical model. The available data was found to limit the operationalization in various ways. First of all, the choice-based nature of the sample data limited the modelling approach and as a result the empirical model **could not capture correlations between (unobserved) utilities of alternatives**. Moreover, the total number of observations was rather limited. Hence, **effects of various correlating variables could not be told apart** and car ownership could only be estimated up to 2 or more cars, and in case of carsharing participation only up to 1 or more cars. Last, the data only contained information on part of the hypothesized explaining variables and as a result the effect of **numerous hypothesized explaining variables could not be tested**. Major shortcomings of the available data were the lack of information on car travel demand, occupation and employment. Besides, information was missing on many land-use variables and the level of detail of the household's living address (municipality) was found to be too aggregated to successfully link external data sources.

Despite the shortcomings, the data made it possible to estimate a **MNL model on household level with five alternatives**: no car and no carsharing participation (0n); 1 car and no carsharing participation (1n); 2 or more cars and no carsharing participation (2+n); no car and carsharing participation (0rt); and 1 or more cars and carsharing participation (1+rt). In case of carsharing awareness, the respondent is faced the full set of alternatives. If not, only the first three alternatives are available: 0n, 1n, 2+n. Variables that are present in the model, include the following:

- Number of adults in the household
- Number of children in the household
- Age partner of the breadwinner
- Household income
- Education
- Presence of carsharing participants in the social environment
- Urbanization degree of the municipality

5. "What will be the impact of (potential) future developments on the total carsharing participation?"

Based on the model application results, it is concluded that increased carsharing awareness, urbanization, or increased financial prosperity will have a limited effect on carsharing participation. Even in extreme scenario's, carsharing participation is only expected to grow from 1.2% to 1.4% of all household. In contrast, an increased presence of carsharing participants in the social environment is expected to impact the carsharing participation, partly due to the fact that currently only few people know of carsharing participants in their social environment. When everybody in the population is aware of carsharing and knows someone in their social environment that participates in carsharing, round-trip carsharing participation is expected to increase from 1.2% to 5.4% of the population.

6. "What are the possibilities to incorporate a joint model for carsharing participation and car ownership in the Dutch national transport model (LMS)?"

In order to answer this question, the empirical model that is earlier constructed, is adapted such that it takes into account the limitations of the LMS. Due to the absence of a carsharing awareness variable, the model structure had to be adapted (all households are now faced the full set of alternatives, rather than only the people aware of carsharing) and moreover one of the explaining variables (presence of carsharing participants in social environment) had to be excluded from the model.

It can be concluded that these adaptions have significantly impact the model performance: the log likelihood dropped from -1418.5 to -1545.2 and the ρ^2 reduced from 0.398 to 0.380. Apart from the fact this will result in less accurate results in model applications, it is also expected that the model is even less accurate for future year applications because: (1) the two excluded variables are expected to change (considerably) towards the future and (2) changes in these variables are found to have a rather large effect on the carsharing participation compared to other variables currently included in the model. The conditions of the LMS environment thus limit the extent to which carsharing participation can be modelled, especially for future year applications.

At the same time, it is also concluded that currently not all possibilities of the LMS are exploited. A better model is expected when making use of other variables present in the LMS: gender, employment and driving licence possession. Moreover, there are possibilities to include a variable for the average car travel demand per household type, when the employment, age of the oldest person and disposable household income are known.

8.1.2 The final design: Specification of a joint model for carsharing participation and car ownership in the LMS

The final result of this thesis is a choice model that replaces the current initial car ownership model that is feed into the CARMOD program in the LMS. The CARMOD program then calibrates the ASC's to meet national and zonal targets. Next, the model is applied on the synthetic population of both the base year and the future year to determine the number of cars and the carsharing participation in the household. This information can then be used for trip frequency, trip destination, mode choice and time-of day choice.

Regarding the model specification of the LMS best possible model, it can be concluded that the available means only enabled the operationalization of the conceptual model to a limited extent. In this thesis, a first attempt is made by using a multinomial logit model on a household level that distinguishes separate alternatives for combinations of the number of cars and the participation in round-trip carsharing: no car and no carsharing participation (0n); 1 car and no carsharing participation (1n); 2 or more cars and no carsharing participation (2+n); no car and carsharing participation (0rt); and 1 or more cars and carsharing participation (1+rt). The variables that are included in the utility functions include the following: Number of adults, number of children, age category, household income, education, and urbanization degree of the municipality.

Ideally, the joint car ownership and carsharing participation model would also take into account numerous land-use variables (public transport accessibility, parking regulations), alternative characteristics (access time and car availability), and variables that represents the households travel behaviour (anticipated (car) travel demand, distance to work, willingness to use public transport). Moreover, the incorporation of other variables, like the carsharing awareness, the presence of carsharing participants in the social environment, and attitudes such as the environmental concern and the psychological value attached to car ownership, is expected to improve the car ownership and carsharing participation model.

8.2 Discussion

In this paragraph the research is evaluated. First, an interpretation is given on the modelling results. Next, limitations of the research are presented. The paragraph concludes with recommendations for future research.

8.2.1 Interpretation of results

In this thesis, first of all an extensive overview is provided on the existing literature towards carsharing participation modelling. Next, empirical analysis is used to determine factors that explain carsharing participation and to test to what extent a joint model for carsharing participation and car ownership can be incorporated in the LMS. This study provides one of the first quantitative insights in the effect of household level characteristics on the trade-off between car ownership and carsharing participation, based on revealed preference (RP) data.

Revealed preference data is more realistic and objective than stated preference data and therefore this study was able to quantify the effects of factors in a more realistic way than earlier studies did. Nevertheless, the quality of the available data is questionable. Due to poorly phrased questions, the data was often ambiguous or contradicting and in those cases assumptions had to be made. Moreover, the total number of observations was found to be rather low and the representativeness of the sample is debated in terms of spatial distribution. The observed overrepresentation of Amsterdam residents is accounted for by including a dummy variable, but it is questionable whether the sample is other than that representative for the Dutch population. The usage of another sample might thus result in varying results. Hence, this study should be considered as a first explorative attempt, but further research with the help of new data is needed to affirm the findings.

The literature study showed that carsharing usage currently only accounts for a marginal part of the total travel demand (<0.02%) and although the carsharing demand is expected to grow, the scenario studies showed that, in contrast to policy maker's expectations, usage numbers will stay low. Based on these findings, it is questionable whether it is still relevant to include carsharing participation in strategic travel models. At the same time, the low usage numbers in future scenarios might be underestimated, because the used model does not account for changes in the (perceived) service level of carsharing organizations, apart from carsharing awareness in general. In the literature study it was found that non-carsharing participants that are aware of carsharing, have limited knowledge on the actual carsharing service level and often perceive it to be much worse than carsharing participants do (SmartAgent, 2011). When these people become better aware of the positive aspects of carsharing (carefree, reduced costs for low yearly mileages), and gain a more truthful image of the negative aspects of carsharing (car availability, hassle to make a reservation, access time), it can be expected that in reality the number of carsharing participants will exceed the model forecast. Moreover, changes in the actual service level, such as an increased fleet variety, a cost reduction, or an increased supply or availability, might further increase the number of carsharing participants. The increase in perception of the service level is partly covered for via the variable for the presence of carsharing participants in the social environment: people who have carsharing friends are assumed to be better known with the carsharing service level. Changes in the actual service level are however not accounted for at all in the 'best possible model'. Moreover, it should be noted that the variable for the presence of carsharing participants in the social environment is no longer included in the 'LMS best possible model'.

Regarding the variables that were present in the available data and hence could be tested via empirical analysis, it was found that results are largely in line with hypotheses. No results were found that contradict hypotheses, but some of the hypotheses could not be confirmed, because no significant effect was measured. It is however to short-sighted to conclude that hence these factors do not have explaining capabilities, because also other explanations can be thought of:

- First of all, with the help of RP data one can only analyse the impact of factors that are actually varying among observations. During this study, many (externally linked) land-use variables were found to correlate and hence the impact of carsharing supply, public transport accessibility, parking tariffs, and urbanization degree could not be told apart. In those cases, the variety of the observations was too small given the number of available observations. The lack of variety in the observations is partly an effect of the fact that variation in the variables was only available on a municipality level, because this is the level on which external sources are linked. In reality land-use characteristics such as parking tariffs, shared car supply and public transport accessibility vary largely throughout the municipality and an advice for further studies is therefore to ensure a more disaggregated linkage on for example postal code level. Other solutions are an increased number of observations or data collection via an SP study in which variety can be ensured.

- Second, it is expected that in some cases no relation is found because poor proxies were used. Environmental concern is measured via the percentage of green party voters in a municipality, which was motivated by a similar approach in an earlier study (Münzel, et al., 2017). Apart from the fact that this variable was strongly correlating with urbanization level, it is also questionable whether it is a good measurement of the environmental concern. There can be thought of many other reasons that people voted for a 'green party' apart from their sustainable views. Also the usability of the parking tariffs is debatable as a proxy for the ease of parking. Higher parking prices on one hand imply that there is more competition for the available parking spots, but on the other hand parking prices are often implemented to increase the parking availability for the residents by chasing away cars of visitors. Hence, parking tariffs are not necessarily linearly related to access time to the private car and/or the costs for the parking permit. Nevertheless, the variable is currently used in the national LMS model to explain car ownership, albeit on a more disaggregated level (zones instead of municipality).

This thesis is a supplement to existing literature, because carsharing participation modelling for strategic travel demand models has not been researched so far. Besides, earlier studies towards carsharing participation are mostly based on stated preference studies and do not account for the interrelation that exist with car ownership. Moreover, earlier studies did not make a distinction between carsharing participation only and carsharing participation in combination with car ownership. Based on the findings in this report future carsharing participation studies should account for differences between the two groups in terms of education, age and urbanization degree of the municipality.

8.2.2 RESEARCH LIMITATIONS

In the execution of this research, limitations are faced that (potentially) impacted the quality of the findings and that limited the ability to effectively answer the research questions.

The first limitation to point out, is the usage of secondary data that is not collected for the purpose of carsharing participation modelling, instead of collecting a new sample. The usage of the data as provided by TNS NIPO impacted the research in various ways. First of all, the quality of the sample and its representativeness is debated and therefore making the estimation results questionable. Second, the number of observations was low, especially for the carsharing alternatives. Therefore, only few variables were found to result in significant parameters in the carsharing alternatives. Third, the choice-based nature of the sample resulted in the selection of a rather simple modelling approach (MNL), which is from a theoretical point of view not the model that is expected to best represent the underlying choice behaviour. Last, the available data only contained information on a limited part of the hypothesized explaining variables and hence numerous hypotheses could not be confirmed nor rejected. Apart from the fact that explaining variables could not be determined with certainty, this also resulted in a final model that is poorly usable for application, because many important variables are missing. A major shortcoming of the estimated models is that they do not account for the anticipated car travel demand and thus differences in usage costs, while this is a major motivation according to theory. Another important shortcoming, is the fact that no characteristics of car ownership and carsharing are taken into account, although earlier studies have shown that the access time and the car availability of both the private car and the shared car impact the willingness to either share or buy a car (Kim, et al. 2017b; ter Berg & Schothorst, 2015).

The usage of secondary data was motivated by the fact that the collection of new data would have been a costly and time consuming process, given the fact that one would ideally want over 15.000 observations to have a sufficient number of observations for non-carsharing participant, without the need for a choice-based sample. The most efficient way to collect such information, is via the national travel surveys. If we had to adapt the national travel survey and wait for new travel survey outcomes, results would not have been available until halfway 2018 at the earliest. With an intermediate solution in the form of a new survey, similar limitations would have been faced as in the TNS NIPO sample, and hence it is chosen to better use a data set that was already available.

In retrospect, the usage of a more complete foreign dataset might have been a better alternative, although then the problem arises that culture differences may lead to deviating results. To overcome this limitation in future studies, it is recommended to adapt the Dutch yearly travel demand survey (ODiN), such that it can be used for estimation purposes.

Second, limitations were faced by using Revealed Preference (RP) data. In RP data the actual choice set that is considered by the respondent is unknown and might thus deviate from the generated choice set in the choice model. In the 'best empirical model', this is partly covered for by not making the carsharing alternatives available for the people unaware of carsharing, but due to a variety of reasons it can still be questioned whether people aware of carsharing actually considered it at the time they made the decision to buy a car. Hence, it is likely that the carsharing participation alternatives are in reality less often considered, which partly explains the strongly negative alternative specific constants for the carsharing alternatives. Moreover, a downside of RP data is the fact that one cannot control the variation among correlating variables (such as public transport accessibility and urbanization degree) and that it is not possible to measure the effect of variables that do not vary over the observations (such as carsharing costs).

The decision to use RP data, was first of all motivated by the fact that this data was made available for this study, but also because in RP data no hypothetical bias is present and because it could function as a supplement on existing literature towards disaggregate carsharing participation modelling, that is mainly based on SP data. In retrospect, the usage of RP data is therefore still preferred over SP data. Nevertheless, it would have been better if land-use variables were linked on a less aggregated scale to maximize the observed variation and hence for future research it is advised to collect information of the living address on postal code level, rather than municipality level. The limitation that certain variables do not vary among observations, can be overcome by collecting data over a larger time period. Costs for example might differ over time. Moreover, it could be considered to combine RP data with SP data.

Next, some research decision should be pointed out that might need revising for future studies. In these cases, another approach might have been better in retrospect, but due to time constraints, these topics are not looked into anymore:

- Carsharing awareness
  In the 'best possible model', it is chosen to limit the choice set of people unaware to carsharing to the alternatives that do not include carsharing. It is hereby implicitly assumed that people unaware of carsharing have the same choice behaviour as people aware of carsharing, when they would have known about carsharing. This is valid assumption, as long as carsharing awareness is the only point on which two other identical households vary. It is however imaginable that people unaware of carsharing are so for a reason: people know less of things that they are not interested in. People not willing to participate in the sharing economy in general, are thus not deepen themselves in the sharing possibilities.
  Possible solution to overcome this limitation, is to estimate different parameters for different groups of people or to estimate a separate choice model to determine the carsharing awareness of a household. Here, it should also be considered to look into different levels of carsharing awareness, since in this research it

was found that people aware of carsharing in general, still have rather deviating perceptions on the actual product.

- Reference alternative
  Furthermore, in retrospect it is acknowledged that the 0n alternative (no car, no carsharing) might not be the best reference alternative and instead the 1n alternative (1 car, no carsharing) should have been used as a reference. The respondents choosing the 0n alternative in the TNS NIPO sample are likely to be not a good representation of the households in the total population choosing the 0n alternative. This is because almost half of the records (100/199) in the 0n alternative were households living in Amsterdam. For all alternatives, but especially for the reference alternative, it is important that the sample is representative for the population. If the reference alternative is a poorly representative sample, this will affect the value of all parameters, because the parameters quantify the difference compared to the reference alternative. In the final model, this problem is now tackled by using a dummy variable in the 0n alternative for household living in Amsterdam. The 1n alternative is expected to be a more representative reference alternative, because it has relatively fewer observations (19%) of the oversampled Amsterdam households and it is the alternative with the most records: there are around four times as much observations in the 1n alternative as in the 0n alternative. Furthermore, it is still a convenient reference for the interpretation of the parameter results.

8.2.3 Recommendations for further research

Due to the doubted relevance of carsharing participation modelling in strategic travel demand, it is first of all recommended to conduct further studies to the actual market potential of carsharing. Studies that quantified the potential usage numbers of carsharing, are mostly conducted from a hypothetical point of view: people are asked if they would participate in carsharing under conditions that are never reached in practice. A possible approach to gain better insights in the market potential, is to follow the changes in car ownership and carsharing participation in a certain area over several years, while measuring variations in carsharing service level. In this way, it can be measured to what extent improvements in the supply, availability, costs and car fleet will lead to more carsharing participation.

When it is decided to incorporate carsharing in the LMS, further research should be conducted on various topics. Regarding carsharing participation modelling, it is first of all recommended to collect new data for the estimation of such a model, preferably via an alteration to the national transport survey to ensure a large number of observations. With the help of new data, it is recommended to conduct studies towards alternative modelling approaches and to develop a model that also accounts for carsharing and car ownership characteristics, such as the access time and the car availability. Moreover, the joint modelling of carsharing participation with car ownership and public transport memberships requires additional attention.

Next, it is recommended to conduct further studies on the adaptions that are needed in the CARMOD program itself and on how to collect zonal and national targets for carsharing participation in the base- and future year.

A carsharing participation model on its own does not enable a strategic travel demand model to determine the effects of carsharing on the total travel demand. Therefore, further studies are needed to the impact of carsharing participation on trip frequency, trip destination, mode choice and possibly also time-of-day choice.

Last, it is recommended to conduct further studies on how to incorporate one-way carsharing in strategic travel demand models, since this form of carsharing is expecting to experience the fastest growth. In this study it was found that one-way carsharing is primarily an alternative to public transport rather than for the private car, and hence it is not included in the joint model with car ownership.

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APPENDICES

A. Minutes of interviews with carsharing organizations

During this study, several interviews were conducted with experts from the field. Below, the interviews are presented in alphabetical order of the organization: Car2go, Greenwheels, and MyWheels. The minutes of the interviews are written in Dutch, to prevent any misinterpretations due to translation errors.

Car2go

Interviewee: Huub Dubbelman
Company: Mercedes-Benz Nederland (where Car2go is part of)
Job-title: Manager Corporate Communications
Type: Interview
Date: October 23, 2017
Verified: October 24, 2017 by Huub Dubbelman

Totstandkoming in Amsterdam

Om Car2go van de grond te krijgen in Amsterdam, moesten er gesprekken worden gevoerd met alle deelgemeenten. Pas nadat elke deelgemeente overtuigd was, was de gemeente Amsterdam bereid mee te werken. Bij de wethouders van de deelgemeenten heerste vooral frustratie over deelauto's die dagen niets stonden te doen en parkeerplekken bezet hielden; ook als de auto er niet was. Dubbelman geeft aan dat het onjuist is dat Amsterdam Car2go door middel van subsidie mogelijk heeft gemaakt; het kostte veel moeite en er is geen euro subsidie verleend. De gemeente heeft wel een vergunning ontwikkeld voor het zogeheten free-floating parking system voor deelauto's.

Elektrisch rijden

De Smarts van Car2go hebben theoretisch een actieradius van 150-160 km, maar dat is in de praktijk nooit een probleem gebleken. Gebruikers kunnen in de app de laadtoestand van de auto zien en weten op basis van ervaring hoeveel procent ze ongeveer nodig hebben voor een bepaalde rit. Daarnaast staat in de app ook aangegeven waar de vrije laadpalen zijn.

Wat wel een probleem is, is in algemene zin de capaciteit die de laadpalen leveren in Amsterdam. Dat is niet zoveel als in eerste instantie is toegezegd (in kWh), waardoor het opladen langer duurt.

Tot slot geeft Dubbelman aan dat de aanschaf en exploitatie van een elektrische auto altijd nog anderhalf tot twee keer zo duur is als van vergelijkbare auto's met een verbrandingsmotor, waardoor het verdienmodel voor elektrische deelauto's niet eenvoudig is. Op de vraag of mensen bewust kiezen voor de elektrische variant, antwoordt Dubbelman: "Idealisme wordt hier met een kleine letter geschreven".

Overheid

Momenteel wordt in Nederland jaarlijks circa 20 miljard euro belasting geïnd die gerelateerd is aan voertuiggebruik. Hiervan wordt circa 6 miljard euro uitgegeven aan infrastructuur (water, wegen, rail). Van de overheidsinkomsten is circa 2 miljard euro afkomstig van bpm (CO_2-uitstoot belasting). De BPM heeft nieuwe, vooral luxe, auto's in het verleden fors duurder gemaakt. De inkomsten uit bpm zijn de laatste jaren geslonken (van ruim 3,5 naar circa 1,8 miljard euro). Dit komt doordat aan de ene kant er compactere en schonere auto's worden verkocht en aan de andere kant heel veel jong gebruikte auto's uit het buitenland worden gehaald waarvoor aanzienlijk minder bpm hoeft te worden betaald. Het wagenpark is nu dus eigenlijk aan het verouderen, waardoor je een uitgesteld effect van de emissievrije uitstoot van elektrische auto's op de luchtkwaliteit krijgt.

Er is behoefte aan een visiedocument van de overheid. Enerzijds geeft de overheid aan dat ze steeds meer emissievrije voertuigen willen, anderzijds betekent dat ook minder inkomsten. De vraag is hoe de overheid deze inkomstenderving op de lange termijn gaat compenseren.

Factoren deelautogebruik
De belangrijkste reden om een Car2go-abonnement te nemen is gemak. Mensen willen niet de zorg voor een eigen auto hebben en/of het OV duurt te lang. Slechte OV-bereikbaarheid (oost-westverbindingen in Amsterdam zijn er nauwelijks) en het niet hebben van een eigen auto zijn dus belangrijke factoren om een abonnement te overwegen. Voor het daadwerkelijke gebruik zijn daarnaast de weersomstandigheden sterk bepalend.

Effecten abonnement
Het is over het algemeen niét zo dat een deelauto-abonnement leidt tot het wegdoen van de eigen auto. Dit was helemaal in het begin nog wel anders, toen de Gemeente Amsterdam inwoners in het centrum de gelegenheid bood om binnen een jaar hun parkeervergunning terug te krijgen, als het gebruik van een deelauto niet beviel. De wachttijd voor een parkeervergunning in Amsterdam is zes jaar, en het bleek dat veel mensen na een jaar toch de parkeervergunning weer terugvroegen. Als gevolg van Car2go is het totale aantal reizigerskilometers vermeerderd.

Moovel
In Nederland ontbreekt het aan een overkoepelend concept waarin alle mobiliteitsdiensten worden aangeboden. Je kunt niet eenvoudig alle verschillende opties met elkaar vergelijken, maar moet hiervoor naar verschillende websites. In Duitsland is er een app: Moovel. Deze app is een initiatief van Daimler. In de app worden alle opties ('alles wat beweegt', zoals deel- of OV-fietsen, Car2go, taxi(limousines), Uber, trein, bus, tram, Flixbus) vergeleken en daar waar mogelijk aan elkaar gekoppeld voor multimodaal vervoer. Verder kan er met de app ook worden betaald.

Stoppen met abonnement
Een abonnement kan op twee manieren worden gestopt: de klant heeft Car2go niet meer nodig of Car2go accepteert de klant niet meer. Dat laatste kan een gevolg zijn van wangebruik of wanbetaling. Gegevens hierover worden uit privacyoverweging niet gedeeld met derden. Stoppen is bij Car2go niet nodig, omdat er in tegenstelling tot bij andere marktpartijen geen abonnementskosten hoeven te worden betaald. Het komt wel voor dat mensen Car2go minder gaan gebruiken, maar Dubbelman doet verder geen uitspraken over de redenen.

Verifiëren gevonden data
De gemiddelde reistijd is 15 minuten en daarin rijden gebruikers gemiddeld 7 kilometer, hoewel dit ook sterk wisselt met het moment van de dag. Op mijn opmerking dat ik heb gelezen dat de gemiddelde reistijd 20-24 minuten is, antwoordt Dubbelman dat dit aan de hoge kant is en de rijtijd sterk afhankelijk is van de verkeersdrukte.

Gebruikersprofiel
Gedurende de spits is 20% van de Car2go-gebruikers treingebruiker. Ze gebruiken de Car2go als first- of last-mile transport. Ook het feit dat Car2go 10 minuten vooraf te reserveren is, heeft het makkelijker gemaakt. In de spits zijn de gebruikers ook vooral afkomstig van buiten Amsterdam.

In de loop van de tijd is de gebruikersgroep jonger geworden; in het begin waren het meer 50plussers. Daarnaast wordt Car2go ook steeds meer voor zakelijk gebruik ingezet. In de afgelopen twee jaar is het klantenbestand verdubbeld. Dubbelman geeft aan dat dit komt door langere aanrijtijden naar Amsterdam (file), meer zichtbaarheid/bekendheid op straat en bedrijven die anders zijn gaan vergoeden. Met een reistegoed (persoonlijk mobiliteitsbudget) per maand maken werknemers nu ook vaker gebruik van Car2go.

Meer zakelijk vervoer zou kunnen veronderstellen dat de gebruikers gemiddeld een hoger inkomen hebben en een hogere opleiding, maar dit durft Dubbelman niet te duiden.

Tot slot bevinden zich meer mannen dan vrouwen onder de klanten van Car2go, maar harde percentages zijn niet bekend (vraag op mail).

Geen uitspraken
Dubbelman gaf aan geen informatie te willen of kunnen verschaffen over het postcodegebied, de huishoudsamenstelling, het inkomen en het opleidingsniveau van de Car2go-members.

GREENWHEELS

Interviewee: Paul van Merriënboer
Job-title: Manager Marketing
Type: Conversation by phone
Date: October 16, 2017
Verified: November 29, 2017 by Paul van Merriënboer

Verifiëren verzamelde gegevens
De gemiddelde triplengte zit meer rond de 50 dan rond de 40km. Hoewel je moeilijk kan spreken over een gemiddelde trip; er zijn heel veel korte ritten tussen 10-20 km en er is ook weer een piek aan de achterkant. Het (door Ank gevonden) aantal reserveringen van 450.000 is te hoog; wellicht als je de Duitse markt meerekent. Het zit meer op 350.000 – 400.000. De gemiddelde ritlengte van 5u45 klopt wel ongeveer.

Invloed factoren lidmaatschap
Afgelopen twee jaar is er veel veranderd, er zijn veel nieuwe klanten bijgekomen. Er zijn nieuwe abonnementen gekomen; waaronder één die gratis is. Daarnaast is de minimumleeftijd omlaag naar 18 jaar. Paul geeft aan dat vooral gemak belangrijk is: toegankelijker en makkelijker koopbaar. Eerst moest men 3 dagen wachten voordat je lid was. Het gaat erom dat er minder kliks zijn om uiteindelijk in de auto te zitten.

Daarnaast speelt bereikbaarheid van het OV mee. Ongeveer 50% van de Greenwheels klanten gebruikt Greenwheels voor erbij; de overige 50% heeft geen eigen auto. De klanten die geen eigen auto hebben en alleen maar een Greenwheels abonnement, moeten wel een hele goede OV-aansluiting hebben. De auto voor erbij is bijvoorbeeld omdat steden geen 2^{e} parkeervergunning afgeven.

Vergelijking met Duitsland
De markt in Duitsland is veel volwassener. Daar zijn 2 miljoen deelauto gebruikers op 80 miljoen inwoners. In Nederland zijn het er circa 100.000 (wellicht iets meer) op 17 miljoen. Daar heeft slechts 10% van de Greenwheels gebruikers een eigen auto.

In Nederland is er met iedere gemeente los contact en iedereen hanteert andere richtlijnen. Zo is een parkeervergunning voor Greenwheels auto's in Diemen gratis en kost het in Almere 1800 per jaar. In Duitsland is gaat dit heel anders. Daar doet Greenwheels ook zaken met supermarkten, particulieren en soms zelf kerken. In Nederland wordt Greenwheels af en toe wel benaderd door vastgoedinitiatieven om bijvoorbeeld een oplossing te bieden voor de parkeernorm.

Overstap one-way?
Er wordt weleens over nagedacht en waarschijnlijk gaat het hier op termijn wel naartoe, maar voorlopig zijn er nog genoeg andere kansen. Het brengt technische problemen met zich mee (relocation) en het doet ook wat met je propositie naar klanten toe.

Samenwerkingen met gemeente
Het onderzoek zal zeker belangrijk zijn voor gemeenten, nu ervaart Greenwheels dat beleid niet eenduidig is en per gemeente sterk varieert. Daarnaast is het niet vanzelfsprekend dat gemeenten autodeelbedrijven betrekken in hun beleidsvorming. Als voorbeeld wordt de eigen wijk van Merrienboer in de binnenstad Utrecht genoemd. Hier is het aantal parkeerplekken gehalveerd en als alternatief wordt een korting aangeboden op een parkeergarage in de buurt, die echter nog steeds duurder is als de vroegere parkeervergunning. Het zou hier bijvoorbeeld handig zijn geweest om de buurtbewoners als alternatief een abonnement voor een deelauto

bedrijf aan te bieden met een bepaald tegoed. Dan gaan mensen ook veel bewuster nadenken over wanneer ze de auto nemen. Nu is het een gemiste kans.

Aan de andere kant is Greenwheels ook weleens actief betrokken door een gemeente, waarbij het doel was om moeder overdag meer bereikbaar te houden.

Type: Interview
Date: October 26, 2017
Verified: November 29, 2017 by Paul van Merriënboer

Greenwheels is in 2014 overgenomen door PON en Volkswagen

Starten met autodelen
Om mensen aan het autodelen te krijgen, is het belangrijk om de drempel zo laag mogelijk te houden. De inschrijfprocedure moet snel zijn (Greenwheels mikt op 2 minuten) en geen vragen oproepen. Tot 2015 was het zo dat klanten eerst elf een contract moeten printen, ondertekenen en opsturen en enkele dagen later kregen ze dan een Greenwheels pasje thuisgestuurd. Nu kan iemand vijf minuten later in de auto zitten.

Daarbij geeft Greenwheels soms een incentive door de eerste rit gratis aan te bieden. De gedachte is dat mensen vooral nog bekend moeten worden met het principe en vervolgens sneller overtuigd zijn.

Greenwheels ervaart dat mensen vaak niet precies weten wat een deelauto is. De verwachte oorzaak hiervan is dat Greenwheels eigenlijk nooit actief gecommuniceerd heeft wat het inhoudt. Klantuitbreiding ging vooral door mond-tot-mond reclame en dit leidde tot circa 400 extra leden iedere maand. Sinds de overname ban PON/Volkswagen, is Greenwheels begonnen met actief te communiceren via video's en de pers en nu groeit het aantal leden meer dan drie keer zo snel als voorheen. Belangrijk in deze boodschap is ook het bewustzijn creëren van de kosten van een eigen auto, veel mensen onderschatten deze kosten nog.

Nederland vs Duitsland
Nederland zit nog in de fase dat mensen bekend moeten worden met het principe. Marketing van Greenwheels richt zich in Nederland dan ook vooral op vergelijkingen met andere vervoersmodaliteiten. In Duitsland daarentegen is de markt al veel verder en richt de marketing zich ook op verschillen met andere aanbieders.

Elektrisch rijden
Greenwheels heeft in 2012 een eerste poging gedaan om elektrisch te rijden en daar is toen veel van geleerd. De belangrijkste problemen waar tegenaan gelopen werd:

- Laadinfrastructuur ontbrak; dit moest Greenwheels zelf aanleggen
- Gebruik obstakel; mensen wisten niet goed hoe het gebruikt moest worden, wat ertoe leidde dat auto's vaker dan nodig niet bruikbaar waren.
- Te duur; Elektrisch rijden is aanzienlijk duurder dan auto's op fossiele brandstoffen
- Te weinig actieradius; Niet afdoende voor ritwensen van de klanten

Nu is het zo dat op alle punten momenteel verbeteringen zijn. Greenwheels geeft aan dat de kwestie dus niet is 'of' ze overgaan op elektrisch rijden, maar eerder 'wanneer'. Elektrisch rijden is al wel beschikbaar voor zakelijke klanten die de auto exclusief willen gebruiken.

Toekomst autodelen
Wat de toekomst van autodelen betreft, zijn er drie grote richtingen om in de gaten te houden:

- Elektrificatie
- Autonoom rijden
- Autodeeltechnologie in de auto's

Autodeeltechnologie is nu nog iets wat vooral achteraf wordt ingebouwd, maar net als met de CD-speler, de navigatie en het alarmsysteem, zal dit waarschijnlijk iets worden wat uiteindelijk al standaard wordt ingebouwd. Mensen kunnen in de toekomst bijvoorbeeld steeds makkelijker via hun mobiel iemand anders toegang geven tot hun auto. Tesla is hier al mee begonnen.

Het is moeilijk in te schatten wat de markt uiteindelijk gaat doen en wie uiteindelijk de eigenaren van de deelauto's gaan worden. Van Merrienboer suggereert dat dit uiteindelijk in handen kan komen van grote partijen als banken en autofabrikanten, maar sluit een verdere groei van meer P2P-carsharing ook niet uit. Uiteindelijk denkt hij wel dat beschikbaarheid het belangrijkst zal blijven.

Om ook in de toekomst interessant te blijven, is Greenwheels momenteel meerdere pilots aan het doen. Zo zijn er samenwerkingen met vastgoed ontwikkelaren om parkeernormen te verlagen (dit is wel direct een beslissing voor 30 jaar!) en wordt er gedacht aan manieren om klanten deels eigenaar van een auto te maken, om zo netwerkuitbreidingen te kunnen realiseren zonder de volledige kosten te dragen.

Tot spreekt Van Merrienboer ook de verwachting uit dat autodelen meer gelaagdheid gaat krijgen. Nu wordt een auto vaak nog binnen een bepaalde community gedeeld (met de buurt, binnen het bedrijf), maar in de toekomst is het bijvoorbeeld mogelijk dat hiertussen ook meer gedeeld gaat worden, eventueel afgebakend binnen bepaalde tijdsloten.

Gebruikersprofiel

Van Merrienboer gelooft dat bij de huidige autodelers (de early adopters) duurzaamheid belangrijk is geweest in de keuze om te gaan autodelen, hoewel kosten wel leidend zijn. Bij de potentiële gebruikers zal uiteindelijk de motivatie naar verwachting (nog) meer vanuit de kosten komen.

Vanuit Greenwheels is een eigen onderzoek beschikbaar gesteld waarin de gebruikersdoelgroep wordt gemeten aan de gemiddelde bevolking (najaar 2015). Exacte getallen hierover kunnen niet via dit rapport gepubliceerd worden, maar de belangrijkste conclusies wel:

- Jonge- en middelbare alleenstaanden en paren zonder kinderen of met oudere kinderen zijn duidelijk oververtegenwoordigd.
- In absolute getallen bestaat de klantenkring van Greenwheels vooral uit alleenstaanden en gezinnen.
- Ouderen zijn aanzienlijk ondervertegenwoordigd in het klantenbestand van Greenwheels.
- Greenwheels gebruikers verdienen beduidend meer; bijna 40% persoonlijk inkomen van 2x modaal of hoger, tegenover 23% van de bevolking
- Greenwheels gebruikers zijn veel vaker tweeverdieners
- Gebruikers zijn zeer hoog opgeleid (Bijna 70% HBO+). Heel duidelijk verband; hoe hoger de opleiding, hoe beter vertegenwoordigd in het klantenbestand.
- Klanten wonen relatief vaker in grachtenpand, flat/appartement en etagewoning/maisonette
- WOZ-waarde woning gemiddeld stuk hoger.
- Er is wel minder autobezit onder Greenwheels gebruikers, maar alsnog heeft 60% minstens 1 auto in het huishouden. Auto's zijn relatief vaker auto's uit het klein-middensegment, het middensegment of het grote segment en zijn vaak jonger dan 8 jaar.

Onderscheid gebruikers

Bij Greenwheels is een duidelijke groep van zakelijke gebruikers te onderscheiden, al dan niet via de mobiliteitskaart, zoals de NS-businesscard. Het is voor deze gebruikers een pré dat alles op één factuur terecht komt, dat vergemakkelijkt het declareren bij de werkgever.

Stoppen met Greenwheels

Mensen zijn gemiddeld 4 jaar lid bij Greenwheels. Van Merriënboer geeft aan dat er een verschil is tussen type gebruikers. De idealist rijdt z'n hele leven. De praktische gebruiker heel kort. Een derde groep voor een bepaalde levensfase. Klanten geven na het opzeggen van het abonnement aan nog steeds zeer tevreden te zijn over

Greenwheels, maar te willen stoppen omdat ze meer kilometers zijn gaan rijden of een leaseauto hebben gekregen. Daarnaast komt het voor dat mensen verhuizen naar een plek waar nog geen Greenwheels. De meeste verzoeken voor nieuwe locaties komen ook van mensen die lid zijn (geweest).

MyWheels

Interviewee: Aron Vaas
Job-title: Chief Operating Officer
Type: Interview
Date: October 16, 2017
Verified: October 31, 2017 by Aron Vaas

Over MyWheels

MyWheels heeft zijn oorsprong in 1993. Het begon klein met de oprichter die een auto deelde met buurtgenoten. In 2003 werd als vervolgstap Wheels4All opgericht, waarbij auto's van Wheels4All aangeboden werden voor particulier deelgebruik. Vanaf 2011 is de P2P-markt er ook bij getrokken en is de naam veranderd in MyWheels. Momenteel wordt circa de helft van de ritten gemaakt in MyWheels auto's en de andere helft in particuliere auto's. Wel is het aanbod van MyWheels auto's veel kleiner dan van particuliere auto's.

Abonnement

De abonnementsstructuur van MyWheels is in de afgelopen jaren enkele malen aangepast. Nu zijn er helemaal geen abonnementskosten meer en is ook de borg afgeschaft. Er zijn nog wel leden die nog een betaald abonnement hebben, zij krijgen een korting per kilometer, dit zijn vooral nog 'heavy users'. Daarnaast zijn er ook mensen die nog een borg hebben staan bij MyWheels, deze krijgen ze terug als ze hun lidmaatschap opzeggen.

Enquête

MyWheels heeft een enquête bij zijn gebruikers afgenomen. De huurders zijn ondervraagd in september 2016; de verhuurders in november 2016. Relevante bevindingen zijn:

- De gebruikers zijn zeer hoog opgeleid (>80% HBO+)
- Meeste huurders hebben geen eigen auto (85,9%)
- Kosten zijn doorslaggevende factor in keuze voor starten met autodelen. Milieuoverwegingen spelen op de achtergrond mee. Dit geld voor zowel huurders als verhuurders.
- Verhuurders zijn voornamelijk mannen (63%)
- Relatief oude doelgroep
- Groot deel wat nog geen smartphone met internet heeft (20%); dit zijn voornamelijk de 'heavy users' (gedefinieerd als >5 ritten per jaar).

Elektrisch rijden

Elektrische auto's zijn, wanneer je alle vaste kosten en belastingen meerekent, uiteindelijk toch nog steeds zo'n 80% duurder dan benzine auto's. De variabele kosten van elektrische auto's liggen wel iets lager, maar niet genoeg om hiervoor te compenseren. De verhouding in kosten per kilometer ligt ongeveer op 10:7 tussen brandstof- en elektrische auto's.

MyWheels Open

MyWheels is bezig met een nieuwe stap: een kastje dat particulieren in hun auto kunnen laten inbouwen waardoor de auto, net als bij de MyWheels auto's, met de smartphone en OV-chipkaart te openen is. Het kastje beschikt ook over GPS, waarmee ook direct het totaal aantal kilometers wordt bijgehouden en de afrekening automatisch kan plaatsvinden. Persoonlijk contact voor de sleuteloverdracht is op deze manier niet meer nodig. In theorie kan de verhuurder dan ook in het buitenland zitten en ondertussen zijn/haar auto aan meerdere huurders verhuren.

Samenwerking gemeenten
MyWheels wordt regelmatig door gemeenten benaderd met de vraag voor het beschikbaar stellen van deelauto's; dit zijn soms hele kleine gemeenten. Onlangs heeft MyWheels ook een afspraak met Nunspeet gemaakt: er komt een deelauto die tijdens kantoortijden voor de gemeente beschikbaar is en buiten kantoortijden door burgers gebruikt kan worden.

Redenen om te stoppen?
Er is weinig inzicht in waarom mensen stoppen, omdat er tegenwoordig ook geen abonnementsvorm meer is. Van de mensen die de borg hebben teruggevraagd, geeft 37,2% aan een auto te hebben gekocht, 25,6% gebruikt MyWheels te weinig en daarnaast geeft een deel aan de borg bijvoorbeeld ergens anders voor nodig te hebben (6,2%) of via een erfenis een auto hebben gekregen.

Zwarte lijst
MyWheels is momenteel samen met Greenwheels bezig om een zwarte lijst op te stellen. Het staat nog niet precies vast hoe deze gegevens uitgewisseld gaan worden (te denken valt aan bijvoorbeeld rijbewijsnummer). Een gebruiker kan door verschillende redenen op de zwarte lijst komen, bijvoorbeeld; wangebruik, wanbetaling, maar er zijn ook voorbeelden van ID-fraude. In het verleden zijn er bijvoorbeeld gevallen geweest waarbij een gevonden rijbewijs is gebruikt om een account aan te maken en een auto te huren bij een particulier, die vervolgens niet terug gebracht werd. Door extra beveiligingsmaatregelen is dit nu niet meer mogelijk. Dergelijke dingen gebeuren vaker met particuliere auto's, omdat daar meestal geen GPS-tracker in zit.

Verschil SnappCar
Aron Vaas vermoedt dat de leden van MyWheels iets idealistischer zijn. MyWheels is een not-for-profit organisatie en heeft daardoor waarschijnlijk een grotere gunfactor.

Parkeervergunning
Het is vooral iets Amsterdams om bang te zijn om je parkeervergunning kwijt te raken, in andere steden is de wachttijd veel minder lang en zijn gratis alternatieven vaak veel dichterbij. Overigens is er in Amsterdam wel de spijtoptantenregeling. Dit geeft mensen de gelegenheid om binnen 3 jaar hun opgezegde parkeervergunning weer (zonder wachttijd) terug te krijgen, op de voorwaarde dat ze nog wel op hetzelfde adres wonen.

Parkeervergunningen voor MyWheels zijn heel wisselend per gemeente, zowel in kosten als in behandeltijd, dit kan zelfs per stadsdeel verschillen.

Verschil tussen gebruik MyWheels- en particuliere auto's
Particuliere auto's zijn vaak redelijk voordelig geprijsd en geven soms ook nog de eerste 100km gratis weg. Afstanden en reistijden verschillen ook; met particuliere auto's zijn deze vaak langer/hoger. De boordcomputer maakt vooral een verschil; voor twee uur autohuur wil je niet moeilijk gaan doen met sleuteloverdracht (van beide kanten). De auto's van MyWheels worden daarentegen regelmatig voor een paar uur gehuurd.

B. Overview of actual car sharing usage in The Netherlands

Information on the actual usage of carsharing is scarce, because providers barely share this information. In this appendix it is aimed to get insight in the actual use by combining sources and information over various years. This appendix focusses on the major suppliers of P2P-carsharing, round-trip carsharing and one-way carsharing. For every provider, it is first aimed to determine the transactions per year; followed by the average trip time and average trip length.

SnappCar

According to a press release of SnappCar (2017), the number of transactions via their platform increased with more than 50% in their working area (Netherlands, Denmark, Sweden) during 2016. By the end of 2016 a car was shared every 10 minutes on average, which would be consistent with circa 4400 transactions per month. Because the source is a press release, it is likely that this number is rounded. One car every 9 minutes would mean 4880 transactions per year; one every 11 minutes equals 3993 transactions. A rise of 50% compared to December 2015, would mean that by the end of 2015, circa 2920 transactions were made per month.

But how to convert this into Dutch numbers? Various sources give information on the supply of shared cars via SnappCar in the Netherlands or the complete working area, see also Figure 22. Numbers of the shared car supply in the complete working area are also known for 2017, however SnappCar extended its working area towards Germany in this year (ANP, 2017) and therefore this number is not used in the graph. Assuming a constant growth in supply and by means of interpolating, one could conclude that SnappCar offered around 19,300 cars in the Netherlands in September 2016. Around the same time SnappCar published a press release stating that on that moment 25.000 cars were available in their complete working area (SnappCar, 2016a), meaning that circa 77% of the SnappCar cars were located in The Netherlands. Between September and December 2017 no expansion of SnappCar's working area took place and because other information is missing, it is assumed that the proportions are unchanged during this period. However, it is questionable if this is a right assumption, since Denmark and Sweden are more recently added towards to working area of SnappCar. According to the technology adoption lifecycle theorem, the adoption of new technologies does not follow a linear growth over time.

If we now assume that the distribution of the supply is an indicator of the distribution of the demand, one could assume that circa 77% of the transactions were made in The Netherlands, meaning circa 3,380 transactions in December 2016. This would roughly mean 40,600 transactions in the period of July 2016 – July 2017, assuming that December is an average month in the timeframe. It should be emphasized that this number is rather unsure; since it is concluded based on many assumptions (constant growth of supply in the Netherlands; unchanged proportions within the working area; supply distribution is indicator for demand distribution; and December is a representative month in the timeframe of a year).

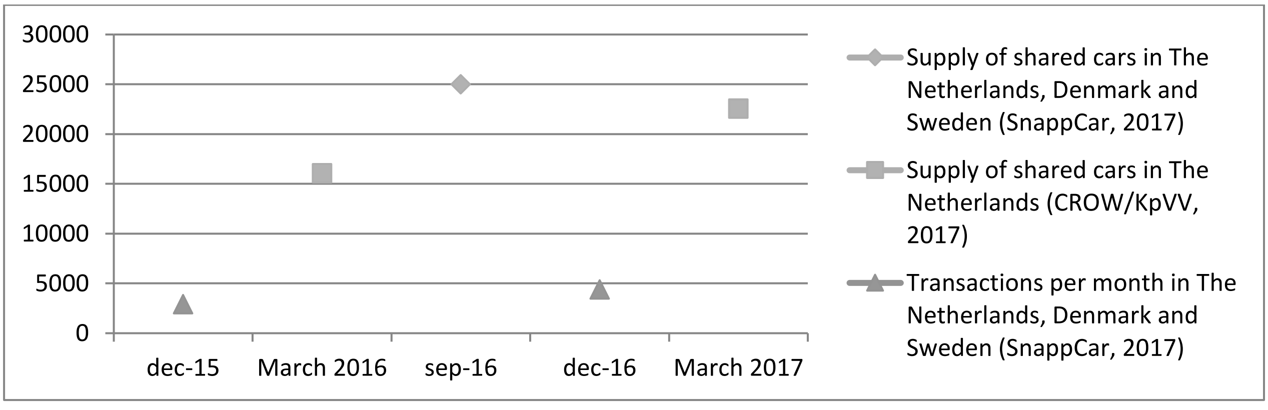


FIGURE 22: SUPPLY OF SNAPPCAR CARS VERSUS NUMBER OF TRANSACTIONS

The average time that a SnappCar is used, varies per month but seems to be unchanged over the years. An article from 2014 reports an average trip time of 1 to 2 days that can runs up to 4 to 5 days during the holiday season (Sprout, 2014). In a press release from August 2016, similar numbers are given: 1.5 day up to 4-5 days in the summertime (SnappCar, 2016b).

SnappCar users drive on average 155 km per day, as stated in an information document for people interested in SnappCar Private Lease[24] (SnappCar & Privatelease.com, 2017). Multiplying this number with the average trip time of 1.5 day, an average trip length of 232.5 km is assumed.

To verify this number, the carsharing monitor of TNS NIPO is consulted, see also Table 32. It can clearly be seen that the average trip distance is likely to be above 50km, although it should be emphasized that the sample group is too small to be representative for all SnappCar users.

TABLE 32: FREQUENCY TABLE OF ANSWERS FROM SNAPPCAR USERS ON THE QUESTION: "WHAT WAS THE TRIP DISTANCE OF YOUR LATEST CARSHARING TRIP?". THE DATA EMANATES FROM THE TNS NIPO SURVEY IN 2014.

Vraag 290: Hoe groot was uw reisafstand (naar het reisdoel) in kilometers van deze laatste verplaatsing? Graag uw beste

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6-10 km	1	7,1	7,1	7,1
	11-20 km	1	7,1	7,1	14,3
	21-50 km	2	14,3	14,3	28,6
	Meer dan 50 km	10	71,4	71,4	100,0
	Total	14	100,0	100,0	

GREENWHEELS

In an interview in August this year, Greenwheels published a growth of 10% in reservations in the Netherlands in the first half year of 2017, which is stated to equal 20,000 extra trips (Berkman, 2017). One can conclude that there are around 220,000 transactions per half year; or 440,000 per year assuming no further growth. This translates to 50 transactions per hour, which is roughly in line with a statement in the same interview that a new trip with a Greenwheels car was starting every minute. In a phone-interview (see Appendix A), Greenwheels stated that the total number of transactions per year is more around 350.000 – 400.000.

The interview with Berkman also gives information on the average trip time, which is 5 hours and 43 minutes. Earlier information stated that the average trip time increased with 24 minutes between 2015 and 2016 as a result of the introduction of the mobile application that enables users to easily extent their booking while driving (Hilgersom, 2016).

The mobile application also resulted in a growth of 4 km in the average trip length (Hilgersom, 2016), however the original trip length is nowhere mentioned. In the carsharing monitor of TNS NIPO (de Gier, et al., 2014), there are 98 users of Greenwheels that do not make use of any other carsharing organization. They were asked for the trip distance of their last trip, the results are shown in Table 33. To convert this into an average trip distance, the frequencies are multiplied with the average of every bandwidth. The last bandwidth has no upper limit and here an average should thus be assumed.

[24] Via this private lease program, people can lease a car from 99 euro per month on the condition that it is hired out at least two times a month.

TABLE 33: FREQUENCY TABLE OF ANSWERS FROM GREENWHEELS USERS ON THE QUESTION: "WHAT WAS THE TRIP DISTANCE OF YOUR LATEST CARSHARING TRIP?". THE DATA EMANATES FROM THE TNS NIPO SURVEY IN 2014.

Vraag 290: Hoe groot was uw reisafstand (naar het reisdoel) in kilometers van deze laatste verplaatsing? Graag uw beste

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 km	8	8,2	8,2	8,2
	6-10 km	12	12,2	12,2	20,4
	11-20 km	21	21,4	21,4	41,8
	21-50 km	25	25,5	25,5	67,3
	Meer dan 50 km	31	31,6	31,6	99,0
	weet niet	1	1,0	1,0	100,0
	Total	98	100,0	100,0	

To make a solid assumption, the cost structures of Greenwheels and an average rental company (Autohopper, 2017) are studied, see also Table 34. In both situations a manual *Volkswagen up!* is assumed that is driving on petrol. It should be noted that the insurance risk is 350 at Greenwheels and 500 at the rental company. At Greenwheels, the current cost structure of the 'Regelmatig' membership is assumed (Greenwheels, 2017). It should be noted that the cost structure has changed over the last few years, but it is unknown in which way. For the rental company, costs are picked as if rented today (October '17). The petrol usage is assumed to be 4,7L per 100 km, which is the average of user experiences as reported on AutoWeek.nl (AutoWeek.nl, 2017). The petrol costs are set on €1.45 per litre.

TABLE 34: COST COMPARISON BETWEEN GREENWHEELS AND A RENTAL COMPANY FOR A VOLKSWAGEN UP FOR VARIOUS TRIPS

VW Up - manual - gasoline	Greenwheels 'Regelmatig'	Rental company
100 km; 4hr	€ 43.00	€ 38.82
150 km; 6hr	€ 64.50	€ 51.22
150 km; day	€ 79.50	€ 51.22
200 km; day	€ 93.00	€ 63.63
200 km; weekend	€ 113.00	€ 67.63
300 km; weekend	€ 140.00	€ 85.63

It is found that Greenwheels is particularly interesting for trips that are made in a relative short time frame and have a low mileage. When trips tend to become longer, rental companies become more financially attractive. However people will not always opt for the most economic option, since ease of use is also important. Greenwheels offers the possibility to pick-up a car without personal interaction, it is just simply a click on the button and the car can be picked up around the corner. Therefore one could assume that people are willing to pay more for a Greenwheels car; however trips above 150 kilometres are assumed to be barely made due to the costs difference. Assuming an average trip distance of 100km in the upper bandwidth; would result in a total average trip distance of 46km. However, 100km might be rather high, since almost 70% of the trips is below 50km. When we would assume that the average of the upper bandwidth is 70km; the total average trip distance would be 36km. Based on this calculations, it is expected that the actual trip length was in the range of 36 to 46 in 2014, when the carsharing monitor was conducted. If we sum that with the extra 4km in trip distance as a result of the mobile application (Hilgersom, 2016), we end up with an average trip distance in the range of 40 – 50km nowadays. This number is also verified with Greenwheels; in a phone conversation (Appendix A) Greenwheels told that the average is more towards 50 than 40. Based on this information, the average is set on 45-50. However, Greenwheels warned that there is no such thing as an average trip distance, because there is a peak around 15-20 kilometres and another peak in the longer trips.

CAR2GO

Car2go, a car sharing provider in Amsterdam, reported a growth in trips of 24% in the first quarter of 2017 compared to a year before. The number of members increased in the same period with 27% to 45,400, thus a growth of 9,650 members (Car2go, 2017). During this period, the number of cars stayed unchanged (CROW/KpVV, 2017). The only information that can be found on the number of reservations, traces back to January 2014. On that moment, Car2go had 17,500 members, 300 cars and 10,000 reservations per week, which equals 520,000 transactions per year (Oplaadpalen.nl, 2014). Because of the growth in members and car fleet, it is expected that the numbers of reservations also increased, however the actual amount is unsure. Below, various scenarios are calculated:

- If we would assume that the number of cars has a linear relationship with the total number of transactions, the total number of transactions in 2014 (520,000) can be multiplied with (340/300); resulting in 590.000 trips in March 2017. However, this is unlikely, since a growth of 24% in trip frequency is realised without any growth in cars. Adding 24% to the estimated 590.000 trips, results in a total trip frequency of around 732,000. This number is still expected to be an underestimation, because it does not account for non-linear growth in relation to the number of cars before January 2016.
- Assuming that the amount of members is a better indicator, an assumed linear relation would result in a total number of transactions of 45,400/17,500 * 520,000, which equals around 1,350,000. However, this is unlikely too, since the competition for the cars have increased, because the cars have to be shared with more users. Car2go mentioned that they want to have more cars in Amsterdam, but are restricted by the municipality to place more cars (see Appendix B). This indicates that the number of cars is indeed a restricting variable.
- Another scenario is to assume a constant growth of 24% per year. This scenario would imply a total number of transactions of around 990,000 in January 2017. This number seems reasonable, since it is within the expected bandwidth of 732,000 to 1,350,000.

Based on these scenarios, one can assume that the total number of trips is probably between 732,000 and 1,350,000 per year, with the best estimation to be 990,000.

To put this numbers into perspective, it is interesting to look at the availability of cars. Assuming an average trip time of 20 minutes (see below), 1,350,000 transactions per year would indicate that the cars are on average used 3 hours and 40 minutes per day, which is around 15% of the total time in a day. In other words, that would equal an average availability of 85%. Let us now assume that, when none of the cars is rented out, on average 2 to 3 cars are within acceptable access distance. This means that there would be a chance between 97.8 and 99.6% that at least one of the cars is available. However, the availability varies largely during the day, just as the location of the cars.

In the TNS NIPO Monitor from 2014, in total 23 car sharers participated that are only using Car2go. The trip distances of their last made trip are shown in Table 35 (de Gier, et al., 2014). It clearly shows that most people were using carsharing for a trip distance in the bandwidth of 6 – 10km in 2014. The average trip length (assuming an average of 60km in the upper bandwidth) is around 13km, but in reality this could vary due to the small sample. However, it is in line with the earlier found results that the average trip distance seems to be decreasing.

TABLE 35: FREQUENCY TABLE OF ANSWERS FROM CAR2GO USERS ON THE QUESTION: "WHAT WAS THE TRIP DISTANCE OF YOUR LATEST CARSHARING TRIP?". THE DATA EMANATES FROM THE TNS NIPO SURVEY IN 2014.

Vraag 290: Hoe groot was uw reisafstand (naar het reisdoel) in kilometers van deze laatste verplaatsing? Graag uw beste

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 km	3	13,0	13,0	13,0
	6-10 km	14	60,9	60,9	73,9
	11-20 km	3	13,0	13,0	87,0
	21-50 km	2	8,7	8,7	95,7
	Meer dan 50 km	1	4,3	4,3	100,0
	Total	23	100,0	100,0	

As stated in an online blog article of November 2016, the average Car2go trip takes 29 minutes, in which 7 km is travelled (Blokland, 2016). In the same article it is stated that over 13 million kilometres are driven and around 280.000 trips are made with the Car2go's in Amsterdam in the period of 2011 to 2016, which corresponds to an average trip length of 46.4 kilometres. From this information one can conclude that the average trip length reduced significantly over the years. Unfortunately the writer of the blog article does not use any references, making the numbers questionable.

In October 2017 another source reported an average trip time of 20-24 minutes (Automobiel Management, 2017). The writer of the article mentions that numbers stated in the article are based on numbers of Car2go, but the exact source remains unknown. The reduced trip time is in line with the assumed trend that trip distances are becoming shorter. Assuming an equal average speed; this means that the trip distance might have decreased further to 5.3 km.

In an interview with Car2go as part of this research in October 2017, the above numbers were verified (see Appendix A). Car2go stated that the average trip time was 15 minutes and the average trip length was around 7 kilometres. No information was given on the total number of trips due to competition concerns. The average trip time of 15 minutes seems rather low compared to the distance and average trip times found in the other sources above. It should be noted that the representative of Car2go was a spokesman of Mercedes-Benz in general and was not specialized in Car2go. During the interview many specialized questions on actual numbers or percentages could not be answered, but were later sent via mail to be verified with colleagues. It could thus be that the interviewee did not know the exact average trip time as well.

C. Cost overview of carsharing organizations in The Netherlands

Below an overview is given of all cost-related components per carsharing organization. The information in the tables is last updated in March, 2018.

- **B2C round-trip carsharing**

	Monthly costs	Car Type	Costs per hour	Costs per day	Costs per weekend	Costs per week	Costs per km	Min. rental time	Round to nearest
Greenwheels 1 (Soms)	€0	Volkswagen Up! (or Peugeot 107)	€6	€49	€69	€149	€0,32	15 minutes	15 minutes
		Volkswagen Golf	€7,5	€59	€89	€179	€0,37		
		Volkswagen Caddy							
Greenwheels 2 (Regelmatig)	€10	Volkswagen Up! (or Peugeot 107)	€4	€39	€59	€139	€0,27		
		Volkswagen Golf	€5,50	€49	€79	€169	€0,32		
		Volkswagen Caddy							
Greenwheels 3 (Vaak)	€25	Volkswagen Up! (or Peugeot 107)	€3	€29	€49	€129	€0,22		
		Volkswagen Golf	€4,50	€39	€69	€159	€0,27		
		Volkswagen Caddy							

Source: www.Greenwheels.nl

	Registration fee	Car Type	Starting costs per trip	Costs per hour (7:00 - 2:00)	Costs per hour (02:00 - 07:00)	Costs per km	Costs per km (>100km)	Fuel costs	Min. rental time	Round to nearest
ConnectCar	€25	Smart ForFour	€3,50	€3,05	€0,91	€0,26	€0,13	Subsequent calculation	1 hour	30 minutes
		Opel Zafira		€4,27	€1,83	€0,35	€0,17	Subsequent calculation		

Source: www.connectcar.nl

	Car Type	Starting costs per trip	Costs per hour	Costs per day	Costs per km	Fuel costs	Min. rental time	Round to nearest
MyWheels Go (B2C)	Hyundai i10	€2,50*	€ 2,50	€ 25	€ 0,13	€0,13	15 minutes	15 minutes
	Citroën C4 Cactus		€ 2,50	€ 25	€ 0,18	€0,11		
	Kia Soul Johanna		€ 1,50	€ 15	€ 0,15	Charging at station for free; Extra electricity on own costs. Radius is ca 120km		
* The booking fee per trip is €2.50. On top of that, most members also have to be an obligatory insurance fee of €3.50 per day to reduce the deductible excess to €0,-. Only members with an old contract do not have to pay these costs.								

Source: www.MyWheels.nl

- **Free-floating one-way carsharing**

	Registration fee	Car Type	Costs per minute	Costs per 2 hours	Costs per day	Extra kilometres	Min. rental time	Round to nearest
Car2go	€9 (includes travel minutes worth €15 - valid 30 days)	Smart ForTwo	€0,31 (incl. 200 km)	€17,90 (incl. 50km)	€79 (incl. 90 km)	€0,31/km	1 minute	1 minute

Source: www.Car2go.com/NL/nl/amsterdam/

	Registration fee	Car Type	Costs per minute	Costs per hour	Costs per day	Costs per week	Min. rental time	Round to nearest
IONIQ Carsharing	€10	Hyundai IONIQ	€0,25	€12	€60	€300	1 minute	1 minute

Source: www.ioniqcarsharing.nl

- **Station-based & Free-floating one-way carsharing**

Witkar offers two types of one-way carsharing. In Rotterdam & Groningen free-floating carsharing is available. Station-based carsharing is offered between numerous cities in The Netherlands. Pricing structures are the same for both one-way carsharing options.

	Registration fee	Car Type	Costs per minute	Costs per day	Extra kilometres	Min. rental time	Round to nearest
Witkar	€25	Smart ForFour	€0,30 (incl. 0.8334 km)	€54 (incl. 150 km)	€0,25	1 second	1 second

Source: www.witkar.nl

Knowing that the cost structures vary among organizations, it is interesting to check to what extent the actually usage prices differ. Table 36 shows the costs for various trips, for the two largest organizations of each carsharing type. The prices are based on a small city car that is rent during daytime on a working day and without additional costs to buy off the deductible excess (except for MyWheels, since this is obligatory for all members). For the Greenwheels price indication, the tariffs from the 'Regelmatig' costs structure are used, which is available for members who pay a monthly fee of €10,-. In case fuel costs are charged, costs of €0.0933 per km are assumed. For P2P carsharing, the prices of small city cars in Delft region are consulted, as valid in March 2018.

TABLE 36: COSTS FOR VARIOUS TRIPS PER CARSHARING ORGANIZATION.

Trip	Car2go (one-way)	IONIQ carsharing	Greenwheels (round-trip)	ConnectCar (round-trip)	SnappCar (P2P)	MyWheels (P2P)
Average Car2go (6.2 km; 20 min)	€ 6.20	€5.00	€ 3.67	€ 8.16	€17.83	€8.99
Average Greenwheels (47 km; 5h43)	€ 79.00	€60.00	€ 35.69	€ 34.02	€21.64	€25.38
Average SnappCar (230 km; 1.5 days)*	€ 173.50	€120.00	€ 140.10	€ 142.00	€71.97	€64.57
Average NL (19.3 km; 15m45s)	€ 4.96	€4.00	€ 7.21	€ 11.57	€19.05	€12.65
Grocery shopping (10 km; 1.5h)	€ 27.90	€19.50	€ 8.70	€ 11.61	€18.18	€12.55
Day trip (100km; 8h)	€ 82.10	€60.00	€ 59.00	€ 63.23	€32.33	€30.33
***Electric cars have to be charged in the meantime, which Is free of extra costs.**						

D. Cost structures in Germany

To get some idea what a cost structure might look like in a more developed market, it is interesting to look at the cost structures in Germany. In February 2017, Germany counted 1.715 million B2C-carsharing users on a total population of around 82 million (Statista, 2017). The Netherlands counted around 90.000 users in 2014 (Jorritsma, et al., 2015), including people who rent out their own car. The current number of users is unknown, but is assumed to be between 100.000 and 120.000 by both Greenwheels (see interviews, Appendix A) and Das (senior advisor in local climate policy and sustainable mobility at Rijkswaterstaat) on a total population of 17 million people.

The major providers in Germany are Car2go, DriveNow and Flinkster with respectively 670.000; 600.000 and 300.000 members. Car2go and DriveNow are both one-way organizations, Flinkster offers round-trip carsharing. The cost structures of these organizations (see the following pages) are clearly more complex than the ones in The Netherlands. First of all, they all charge some subscription fee and all three organizations offer price reductions or hourly packages for longer trips. The discount may start after 2, 4, 6 or 24 hours and they often vary per city. The two one-way companies have additional charges when picking up or dropping off the car at certain special origins and destinations such as an airport. DriveNow furthermore charges extra costs for reservations made more than 15 minutes in advance, although this is free during the night. During the day, DriveNow does not make any distinction in price between parking and driving costs, although parking is free of charge during the night. Furthermore, DriveNow offers a variety of packages with various discount structures. It is for example possible to buy pre-paid packages (a credit for a certain amount of minutes for a reduced price with an unlimited validity) and saving packages (basically a membership with fixed monthly costs that gives the member a discount on the rates). Last, additional charges have to be paid for driving a convertible in the summer. Flinkster, the third largest carsharing organization in Germany, charges usage costs that depend on the time of day.

Car2go

TARIF/ TARIFF				
Validierungsgebühr Validation fee				9,00 €
Preiskategorien	smart (Benzin)	smart (Elektro)	Mercedes-Benz I (A-Klasse)	Mercedes-Benz II (B-Klasse, GLA, CLA)
Fahren pro Minute 1 minute driving	**0,26 €**	**0,29 €**	**0,31 €**	**0,34 €**
Langstreckentarif wenn Inklusivkilometer überschritten Long distance fee after inclusive mileage is exceeded				0,29 €/km
Inklusivkilometer im Minutentarif (ohne Buchung eines Packages) Included mileage within minute tariff (without booking a package)				200 km
Inklusivkilometer im Package-Tarif Included mileage within package tariff				lt. Anzeige bei Buchung as indicated at booking
Flughafenzuschlag bei Mietbeginn und/oder Mietende an folgenden Flughäfen: Berlin, Hamburg, Köln, Düsseldorf, Frankfurt & Stuttgart Airport fee for rentals starting and/or ending at the following airports: Berlin, Hamburg, Köln, Düsseldorf, Frankfurt & Stuttgart				5,90€
Flughafenzuschlag bei Mietbeginn und/oder Mietende am Flughafen München Airport fee for rentals starting and/or ending at the Munich airport				12,00 €
Zuschlag für Mietende innerhalb speziell ausgewiesener Zonen (Drop off fee)[1] Additional fee for specific zone (Drop off fee)[1]				bis 4,90€

HOW MUCH DO THE CAR2GO PACKAGES COST?

	2h (80 km included)	4h (120 km included)	6h (160 km included)	24h (200 km included)
smart	17,90 €	29,90 €	44,90 €	79,00 €
A-Klasse	19,90 €	34,90 €	49,90 €	99,00 €
CLA / GLA / B-Klasse	22,90 €	38,90 €	53,90 €	109,00 €

Source: www.Car2go.com/DE/en/

DriveNow

Standard fees

Registration	
Standard registration fee	29 €

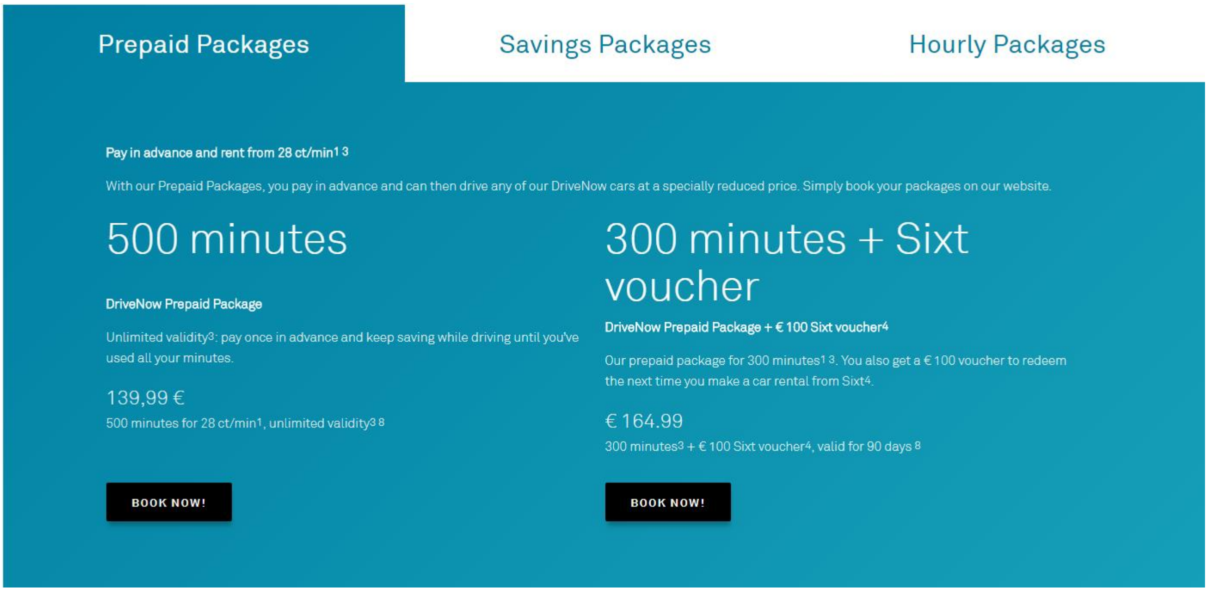
Rental Price Per Minute	
MINI 3 door, 5 door, Clubman	33 ct/Min[1]
MINI Convertible rental (Summer) (1 April to 31 October)	36 ct/Min[1]
MINI Convertible rental (Winter) (1 November to 31 March)	33 ct/Min[1]
BMW 1 Series rental	33 ct/Min[1]
BMW i3, X1, BMW 2 Series Active Tourer, BMW 2 Series Convertible, MINI Countryman rental	36 ct/Min[1]
Drive'n Save[2] Subject to availability and valid only for reserved vehicles	20 ct/Min[1 2] / 24 ct/Min[1 2]

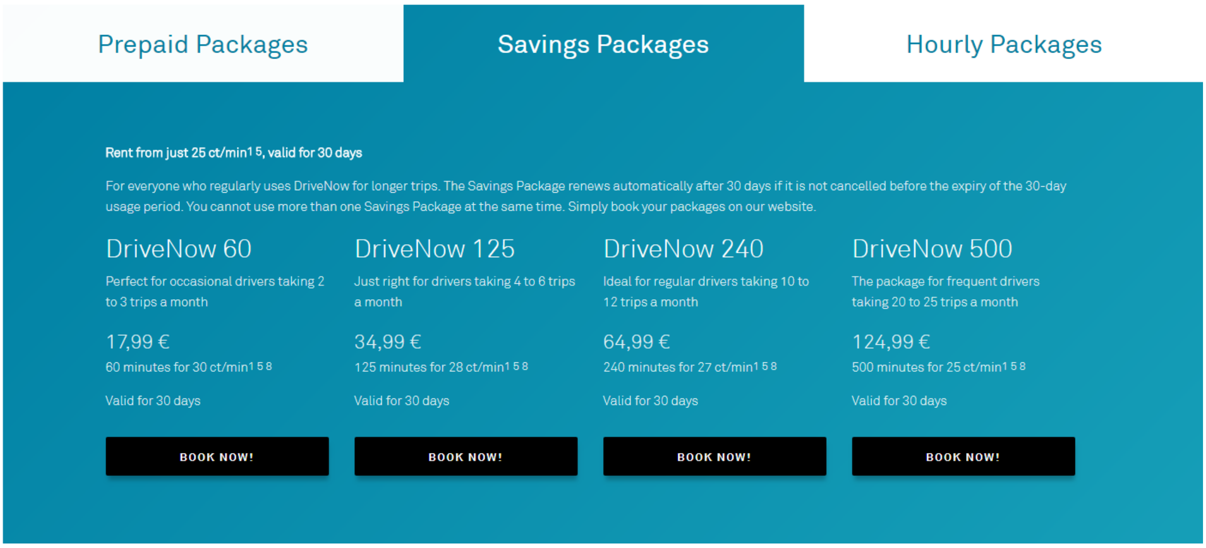
Collision Damage Waiver	
350 € excess Comprehensive cover, incl. theft cover	€ 1 mandatory/rental[1]

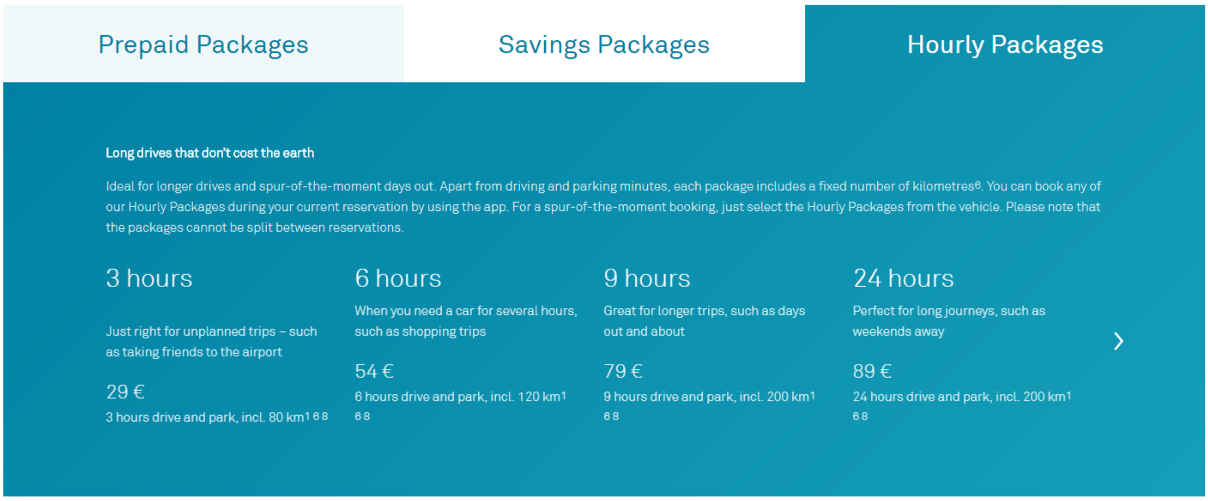
Park & Keep	
Park & Keep Stop off en route without ending the rental	Price according to car model[1]
Park & Keep, Mon to Fri Midnight to 6 AM Cologne and Dusseldorf: Sun to Thurs, from 10 PM to next day 7 AM	Free of charge

Reserving a vehicle	
Reservation for 15 minutes	Free of charge
Extended reservation Max. 8 hours	10 ct/min
Extended reservation Mon to Fri, midnight to 6 AM	Free of charge

Additional fees for special destinations	
Berlin Tegel Airport (at start/end of rental)	4 €
Berlin Schönefeld Airport (at start/end of rental)	6 €
Hamburg Airport (at start/end of rental)	5 €
Munich Airport (at start/end of rental)	12 €
Cologne Airport (at start/end of rental)	4 €
Dusseldorf Airport (at start/end of rental)	6 € / 4 €
Trip from Dusseldorf to Cologne (incl. Chempark Leverkusen) (end of rental)	10 €
Trip from Cologne to Dusseldorf (end of rental)	8 €
Trip from Cologne to Porz (end of rental)	5 €
Trip to Düsseldorf Gerresheim (end of rental from Cologne)	3 €
Trip to Bavaria Film City (Munich) (end of rental)	5 €
Trip to Uni Garching (Munich) (end of rental)	3 €
Trip to Uni Neubiberg (Munich) (end of rental)	3 €
Trip to Großhadern (Munich) (end of rental)	3 €
Trip to Unterschleißheim (München) (end of rental)	5 €
Extended Business Area Munich (calculated from Stachus, max. distance 10 km)	2 € / km
Trip to Kleinmachnow (Berlin) (end of rental)	5 €







Source: www.drive-now.com/de/en

FLINKSTER

Fahrzeug-klassen	Beispiel-fahrzeuge	Stundenpreis 22 bis 8 Uhr	Stundenpreis 8 bis 22 Uhr	Tagespreis 1. Tag	Tagespreis ab 2. Tag	Verbrauchs-pauschale pro Kilometer*
Mini (ohne Navi)	Toyota Aygo	1,50 Euro	2,30 Euro	39,00 Euro	29,00 Euro	0,18 Euro
Klein (teilw. ohne Navi)	Citroën C-Zero, Opel Corsa, Peugeot Ion, Ford Fiesta, VW Polo, Peugeot 207, MINI-E	1,50 Euro	5,00 Euro	50,00 Euro	29,00 Euro	0,18 Euro
Kompakt	VW Golf, Opel Astra, Ford Focus Turnier, Peugeot 307	1,90 Euro	6,00 Euro	60,00 Euro	39,00 Euro	0,18 Euro
Mittel	VW Passat, Ford Mondeo, MB C-Klasse, Toyota Prius Plug-In PHV, Audi A4, Opel Ampera	1,90 Euro	7,00 Euro	70,00 Euro	49,00 Euro	0,20 Euro
Transporter (teilw. ohne Navi)	Ford Transit, MB Sprinter, Opel Movano, VW T5 (Fahrzeuge teilweise mit 9 Sitzen)	1,90 Euro	8,00 Euro	80,00 Euro	59,00 Euro	0,20 Euro
Sonder	Aktionsfahrzeuge	1,50 Euro	2,50 Euro	40,00 Euro	29,00 Euro	0,20 Euro
Extra & Ober (48h Vorlaufzeit)	Audi, A6/A8, BMW 5er/7er, MB E/S-Klasse	auf Anfrage	auf Anfrage	auf Anfrage	auf Anfrage	auf Anfrage

Bruttopreise inkl. geltender MwSt.

* Die Kosten für die Verbrauchspauschale (Strom/Kraftstoff) werden über GPS ermittelt und auf der Rechnung separat ausgewiesen.

Die Verfügbarkeit der Fahrzeugklassen kann nach Standort variieren.

Flughafenzuschlag: 25 % auf den Zeitpreis. Anmietungen an Flughäfen und an weiteren Stationen unseres Mietwagenpartners sind nur zum Tagespreis möglich. Die Betankung erfolgt hierbei auf eigene Rechnung, die Verbrauchspauschale entfällt.

Buchungsbeschränkung
Für unter 25-jährige Fahrtberechtigte gibt es Buchungsbeschränkungen, sodass in diesem Fall nur auf das Fahrzeugangebot der Klassen „Mini", „Klein" und „Transporter" zurückgegriffen werden kann.

Registrierungskosten (einmalig)

Kunden ohne BahnCard	29,00 EUR
Kunden mit BahnCard	kostenfrei
Partnerkundenkarte	10,00 EUR
Führerscheinprüfung per Video	kostenfrei
Führerscheinprüfung in der DB Vertriebsstelle/ im Shop	20,00 EUR

Monatliche Grundgebühr keine

Schäden:
Die Selbstbeteiligung im Schadensfall beträgt 1.500 EUR, sofern nichts anderes im Kundenvertrag festgelegt wurde.

Unfallbearbeitungspauschale:
Wird für die Bearbeitung von Unfallschäden erhoben und orientiert sich am Aufwand 25,00/50,00 EUR

Stand: Mai 2017

Source: www.flinkster.de

E. YEARLY CAR USAGE COSTS FOR BOTH CAR OWNERSHIP AND CARSHARING MEMBERSHIP.

This appendix elucidates on the sources consulted and assumptions made for the determination of car ownership and carsharing costs as presented in Figure 9 on page 21 in this report. Below, first the costs for car ownership are discussed, followed by the cost for car sharing.

Car ownership costs consist of fixed and variable costs. The fixed costs include depreciation costs, private motor vehicle and motorcycle tax, maintenance costs and insurance costs. The height of the amount that has to be paid, differs per type of car, home address of the owner and the insurance preferences. Characteristics of the car that influence the costs, are the purchase price, market value, weight, fuel type, CO2-emission and age. Nibud (2017) aimed to determine the average fixed costs for various car segments, based on the car ownership cost calculator of ANWB (2017), see also Table 37. In the cost calculation, a depreciation time of 10 years is assumed. Apart from fixed costs per year, there are also variable costs per kilometre. Variable costs include depreciation costs, fuel costs and maintenance costs. Maintenance and depreciation costs are thus not only set per year, but also per kilometre. When a car is not used, maintenance will still be needed once in a while. For every extra kilometre driven, extra maintenance is needed. A similar argument can be made for depreciation costs. Variable costs can vary largely and are dependent of the car type. Nibud aimed to determine an average costs per kilometre per segment, which are also presented in Table 37.

TABLE 37: AVERAGE CAR OWNERSHIP COSTS IN EUROS, ITEMIZED PER SEGMENT (ANWB, 2017) (NIBUD, 2017)

	Mini cars	Compact car	Compact midsize car	Midsize car
	(A-segment)	(B-segment)	(C-segment)	(D-segment)
Average fixed cost per year	€ 1,788	€ 2,328	€ 3,144	€4,104
Average variable costs per km	€ 0.17	€ 0.19	€ 0.20	€ 0.23

The yearly costs for carsharing are more complicated, because usage costs are usually based on a (distance and) time component. Moreover, cost structures differ among carsharing types and even among organizations of the same type. Below, first average kilometre costs for one-way carsharing are determined, followed by round-trip carsharing and last comes P2P carsharing. All cost information that is referred to, is derived from the organization's websites and earlier presented in paragraph 2.3 and Appendix C.

The average costs per kilometre for one-way carsharing are presented in Table 38. The table shows the average costs per minute that are charged by IONIQ carsharing (€0.25) and Car2go (€0.31). Since most one-way shared cars are only available in the town centre, the maximum speed is assumed to be 50 km/h. However, because traffic lights and congestion are usually part of the route, it is more realistic to assume an average speed of 30 to 40 km/h. Based on this information, the average costs are expected to be something in between €0.38 and €0.62 per kilometre. It should be emphasized that these costs do not take into account parking time and are thus only valid for car travel demand within the operating area of the one-way organization.

TABLE 38: AVERAGE COSTS PER KILOMETRE FOR ONE-WAY CARSHARING

	€0.25 per minute	€0.31 per minute
30 km/h	€0.50 per km	€0.62 per km
40 km/h	€0.38 per km	€0.47 per km

To determine the costs for round-trip and P2P carsharing, not only assumptions have to be made on the average speed while driving, but also on the time of the activity. To get an idea of the magnitude of the carsharing costs, it is for now assumed that al tours made with a shared car consist of 2 trips (go and return) and a certain activity time. The length and duration of the trips are assumed to equal the average Dutch car trip of 19.3km and 15m45s (ANWB, 2015). Moreover, it is assumed that the total tour is made within the timeframe of a day. It is acknowledged that this is a rather simplified representation and that in practice the trip length will vary with the activity time. The activity time is however much more decisive for the costs than the number of kilometres, and therefore it is decided to only account for variation in the activity time.

To determine the activity time, OViN data from 2016 is consulted. Figure 23 shows the distribution of the activity time of car tours. Only home-based tours are selected in which the respondent's main transport mode is 'car driver' on the outbound trip and also returns by car (either passenger or driver). The data shows a peak around 1 hour and a peak around 10 hours. Around half of the tours (50.3%) have an activity time up to 4 hours and the overall average is 5h30.

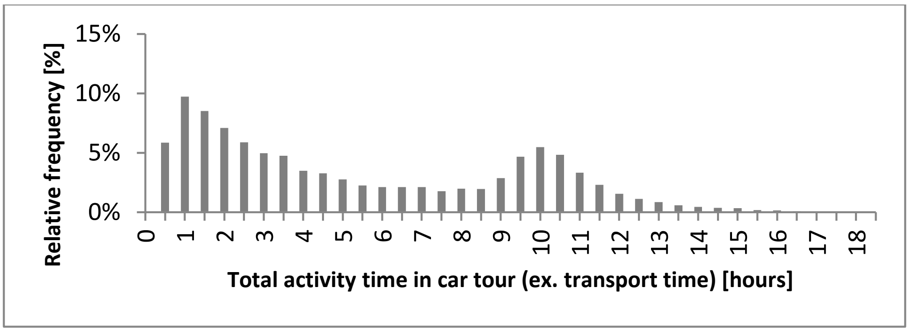


FIGURE 23: DISTRIBUTION OF ACTIVITY TIME IN HOME-BASED TOURS THAT ARE MADE AS A CAR DRIVER WITHIN THE TIME PERIOD OF ONE DAY.

To estimate an average price per kilometre for round-trip and P2P carsharing, the costs for a tour with 1 hour activity time and the costs for a tour with 10 hours activity time are calculated for the three major round-trip organizations and for each of the tours the average price per kilometre is determined, see also Table 39 and Table 40. The calculation is made based on the costs as attached in Appendix C. If subsequent calculation for fuel cost applies, costs of €0.0933 per kilometre are assumed.

TABLE 39: ROUND-TRIP CARSHARING COSTS

	Greenwheels	ConnectCar	MyWheels Go	Average costs	Average price per km
Two average trips (go and return) and 1 hour activity time (38.6km; 1:31:30)	€ 17.42	€ 23.24	€14.41	€18.36	€ 0.48
Two average trips (go and return) and 10 hours activity time (38.6km; 10:31:30)	€ 49.42	€ 53.74	€35.04	€ 46.07	€ 1.19

TABLE 40: P2P CARSHARING COSTS

	SnappCar	MyWheels P2P	Average costs	Average price per km
Two average trips (go and return) and 1 hour activity time (38.6km; 1:31:30)	€ 20.85	€ 16.61	€18.37	€ 0.49
Two average trips (go and return) and 10 hours activity time (38.6km; 10:31:30)	€ 26.60	€ 29.65	€ 28.13	€ 0.73

As can be seen, costs per kilometre vary largely with the activity time. To get an idea of the average kilometre costs, it is now assumed that around 50% of the tours are made for the lowest price per kilometre and the other half for the highest price per kilometre. Round-trip carsharing would then have average usage costs of €0.84 per kilometre. In the same way, the costs for P2P carsharing are estimated on €0.61 per kilometre.

It is acknowledged that the calculation is rather arbitrary, because it assumes that the relative activity time distribution is constant. In reality it is expected that households with a higher yearly travel demand are likely to have a different distribution pattern: they will not only make more trips, but also longer trips. Besides, carsharing participants are expected to adapt their travel behaviour as a result of the costs. For expensive tours it is expected that other modes are considered. At the same time it is expected that the shared car is less often used for very short distances, because of a higher access time, the need for reservation, and the higher variable costs compared to the private car. Moreover, when a household has access to both a private- and a shared car, it is likely that the shared car is used for the least expensive trip. Last, it can occur that more than 2 trips are made within a tour. It is therefore assumed that in reality the average costs might be somewhat off and as a result a margin of ±15% is accounted for. Round-trip carsharing is thus expected to costs €0.71 – €0.96 per kilometre and P2P carsharing €0.52 - €0.70 per kilometre.

Figure 24 shows a graph in which the above estimated carsharing- and car ownership costs are plotted against the yearly travel demand. As can be seen, car ownership is already financially interesting from 3,000 – 5,500 kilometres, but varies with the preferred car type and the carsharing organization. It should be emphasized that for most households it will not be feasible to travel all car travel demand by one-way shared car, since the working area of one-way carsharing is rather limited on the moment.

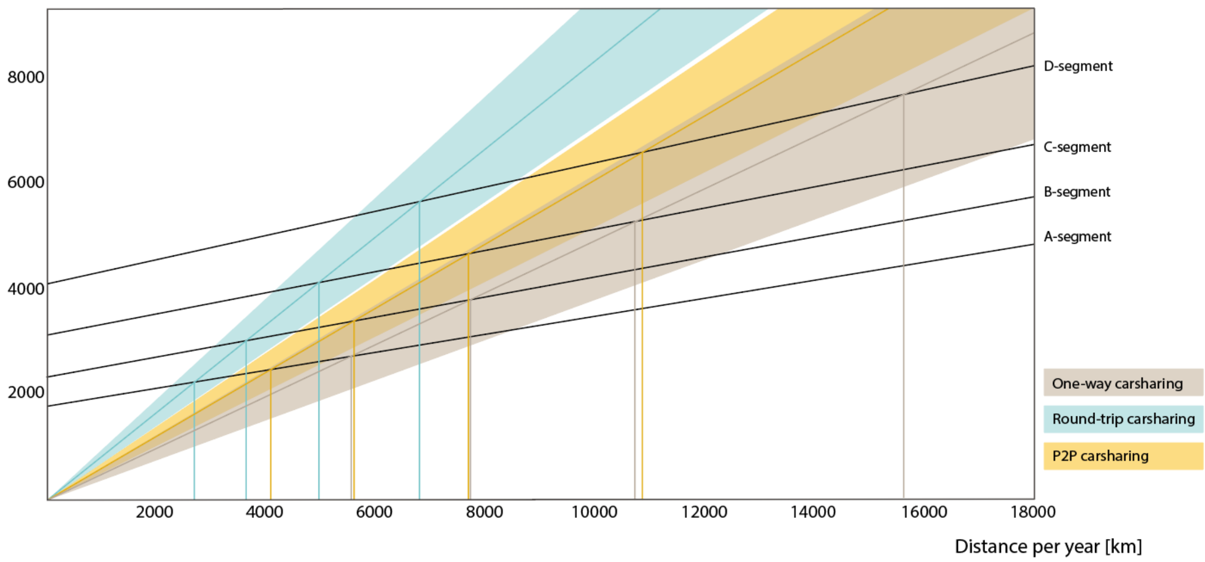


FIGURE 24: CAR OWNERSHIP COSTS VERSUS CARSHARING COSTS BASED ON MILEAGE PER YEAR

To test the viability of the graph, it is interesting to check what other studies tell about the financial turning point. Boston Consulting Group (Bert, et al., 2016) compared the costs for car ownership with the costs for carsharing in Europe, based on mileage per year, see also Figure 25. As can be seen, a distinction is made between various types of cars. For the costs of carsharing a heavy user and a regular user is considered, since costs are usually lowered for heavy users. The report does not explain how the figure is established, but some information can be deduced from the figure. It seems that the average costs for carsharing for heavy users are assumed to be around €0,53 per kilometre (€16,000/30,000km), the costs for light users are around €0,65 (€19,500/30,000km) per kilometre according to the figure.

The carsharing costs as presented by BCG are averages for Europe. According to Eurostat (2017), the price level index of The Netherlands in relation to Europe equals 111. If we would correct the costs with this factor, costs of €0.59 – €0.72 per kilometre can be expected in The Netherlands. In general, this is in line with the estimated costs as presented in Figure 24; although one-way carsharing is slightly cheaper and round-trip carsharing is slightly more expensive per kilometre.

In contrast, the breakeven points vary significantly, which is the result of a different estimation of the car ownership costs. Based on Figure 25, it seems that the fixed costs per year are much higher. On the other hand, the variable costs are much lower: around €0.05 per kilometre. Furthermore, no distinction seems to be made in variable costs per segment. Unfortunately BCG does not clarify how they got to the numbers and therefore it is assumed that the indication of ANWB and Nibud is more reliable for the Dutch car ownership costs.

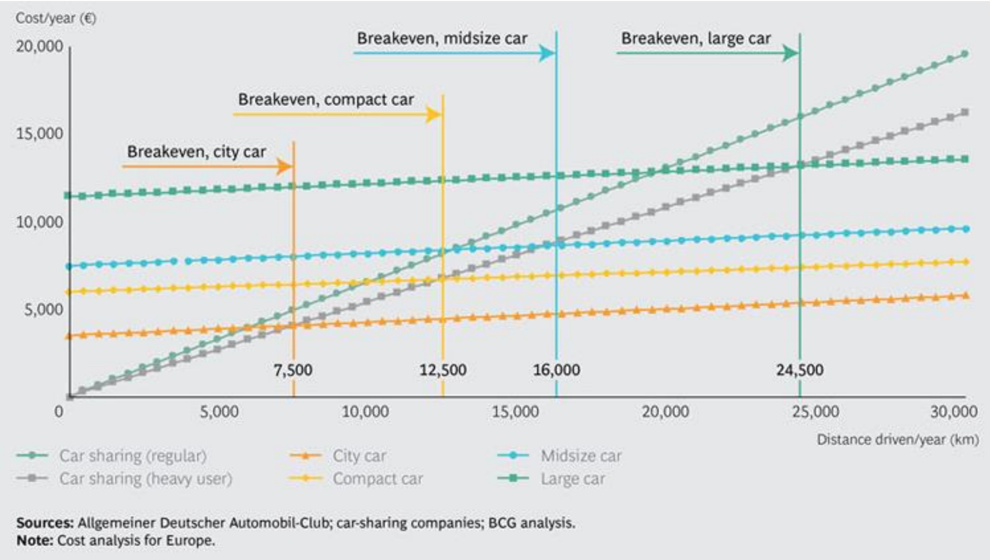


FIGURE 25: TOTAL YEARLY COSTS: OWNED VERSUS SHARED CARS (BERT, ET AL., 2016)

F. Questions asked in TNS NIPO survey

Below an overview is given of all questions that are asked in the TNS NIPO survey. The questions are asked in Dutch and to prevent misinterpretation due to translation errors, the list below is also provided in Dutch.

Question	Round 1	Round 2	Round 3
Maakt u of iemand anders binnen uw huishouden weleens gebruik van een deelauto, of verhuurt u of deze persoon weleens de eigen auto?	x		
Algemene vragen			
Aan welk(e) activiteit(en) besteedt u uw meeste vrije tijd?		x	
Beschikt één of meerdere personen in uw huishouden over een eigen auto/lease auto of auto van de zaak		x	
Hoeveel auto's zijn er beschikbaar in uw huishouden (eigen auto's, lease auto's, auto's van de zaak)?		x	
Voordat u overging op het gebruik van een deelauto, over hoeveel auto s had u toen de beschikking?			x
Over hoeveel auto's heeft u nu de beschikking?			x
Wat is het merk van uw huidige auto?			x
Wat is het bouwjaar van uw huidige auto?			x
Op welke brandstof rijdt uw huidige auto?			x
Heeft u weleens gehoord of gelezen over autodelen of deelauto's?		x	
Welke van de volgende situaties vallen volgens u onder 'autodelen'?		x	
Had u voor u dit had gelezen weleens gehoord of gelezen over autodelen of deelauto's?		x	
Welke organisaties kent u die u zou kunnen inschakelen om een deelauto van te huren?		x	
Welke organisaties kent u die kunnen bemiddelen om een deelauto te huren van een particulier?		x	
Welke organisaties kent u die u zou kunnen inschakelen om uw eigen auto te verhuren?		x	
Van welke van de onderstaande aanbieders op het gebied van autodelen heeft u weleens gehoord?		x	
Kent u mensen in uw omgeving (familie, vrienden, collega's) die aan autodelen doen?		x	
Hoe staat u in het algemeen tegenover het initiatief van autodelen?		x	x
U ziet hieronder een aantal uitspraken over autodelen. In hoeverre bent u het met deze uitspraken eens of oneens?		x	x
Hoe staat u tegenover het verschijnsel crowdfunding waarbij de lancering van een initiatief (bijvoorbeeld een nieuw product) afhankelijk wordt gesteld van financiële participatie door grote groepen particulieren?		x	
Heeft u in de afgelopen 12 maanden (met bemiddeling van een organisatie) een auto gehuurd van een particulier? Of bent u van plan om dit in de komende 12 maanden te gaan doen?		x	x
Heeft u in de afgelopen 12 maanden een auto gehuurd van een organisatie? Of bent u van plan om dit in de komende 12 maanden te gaan doen?		x	x
Heeft u in de afgelopen 12 maanden uw eigen auto verhuurd aan een particulier via een organisatie? Of bent u van plan om dit in de komende 12 maanden te gaan doen?		x	
Heeft u in de afgelopen 12 maanden uw eigen auto uitgeleend aan een bekende (familie, vrienden, kennissen)? Of bent u van plan om dit in de komende 12 maanden te gaan doen?		x	
Kunt u in onderstaand schema aangeven hoe vaak en met welke vervoermiddelen u reist?		x	x
In onderstaand schema ziet u verschillende verplaatsingen. Kunt u in het schema aangeven welke vervoermiddelen u het vaakst gebruikt bij de getoonde verplaatsingen?		x	
Beschikt u over een openbaar vervoer abonnement?		x	

Blok autodelers		
U huurt een deelauto van een organisatie. Waarom heeft u er niet voor gekozen om een deelauto van een particulier te huren?	x	x
U huurt een deelauto van een particulier. Waarom heeft u er niet voor gekozen om een deelauto van een organisatie te huren?	x	x
Wie of wat heeft u geraadpleegd bij het besluit om te gaan autodelen?	x	
Hadden deze personen zelf ervaring met autodelen?	x	
Bij welke van onderstaande aanbieders heeft u een deelauto gehuurd?	x	x
In welke mate was het voor u makkelijk of juist moeilijk om er achter te komen wat de specifieke voordelen van de verschillende organisaties zijn?	x	
Waarom heeft u voor <genoemde organisatie> gekozen?	x	x
In welk jaar bent u met autodelen gestart?	x	x
Kunt u aangeven voor welk reisdoel u de laatste keer een deelauto heeft gebruikt?	x	
Hoe groot was uw reisafstand (naar het reisdoel) in kilometers van deze laatste verplaatsing?	x	
Hoe groot was de reisafstand in kilometers van uw laatste rit met een deelauto waarbij u zelf bestuurder was		x
Heeft u deze laatste rit met de deelauto in het weekend of op een doordeweekse dag gemaakt?		x
Wat was de vertrektijd van deze laatste rit met de deelauto? uur + minuten:		x
Wat was de aankomsttijd van deze laatste rit met de deelauto? uur + minuten:		x
Van of via welke organisatie heeft u deze deelauto gehuurd?		x
Wat was het merk van deze deelauto?		x
En wat was het bouwjaar van deze deelauto?		x
En op welke brandstof reed deze deelauto?		x
Stel dat u voor deze rit niet de beschikking had over een deelauto, welk vervoermiddel had u dan gebruikt?		x
Kunt u aangeven waarom u voor deze verplaatsing een deelauto in plaats voor een ander vervoermiddel heeft gekozen?	x	
Hoe groot was de reisafstand in kilometers van uw een na laatste rit met een deelauto waarbij u zelf bestuur		x
Heeft u deze een na laatste rit met de deelauto in het weekend of op een doordeweekse dag gemaakt?		x
Wat was de vertrektijd van deze een na laatste rit met de deelauto?		x
Wat was de aankomsttijd van deze een na laatste rit met de deelauto?		x
Van of via welke organisatie heeft u deze deelauto gehuurd?		x
Wat was het merk van deze deelauto bij uw een na laatste rit?		x
En wat was het bouwjaar van deze deelauto bij uw een na laatste rit?		x
En op welke brandstof reed deze deelauto bij uw een na laatste rit?		x
Stel dat u voor deze rit niet de beschikking had over een deelauto, welk vervoermiddel had u dan gebruikt?		x
Welke reden heeft u om aan autodelen te doen? Geeft u s.v.p. de redenen aan in volgorde van belang. Dus eerst de belangrijkste reden, vervolgens de reden die daarna het belangrijkst is, etc.	x	
Welke nadelen zitten er wat u betreft aan het gebruik van een deelauto (niet het uithuren maar het huren ervan)?	x	
Welke nadelen zitten er wat u betreft aan het verhuren van uw auto als deelauto?	x	
Zou u anderen het huren van een deelauto aanbevelen?	x	
Zou u anderen het verhuren van de eigen auto aanbevelen?	x	
Voordat u begon met autodelen: welk vervoermiddel gebruikte u toen voor de verplaatsingen waarvoor u nu een deelauto gebruikt?	x	x
U geeft aan dat u voordat u een deelauto gebruikte, gebruik maakte van een eigen auto. Wat was het merk van de auto die u heeft vervangen voor een deelauto?	x	x
Wat was het bouwjaar van deze auto?	x	x
En op welke brandstof reed de auto die u heeft vervangen voor een deelauto?		x
Hoeveel kilometer werd er per jaar met deze auto gereden?	x	

Kunt u aangeven of het gebruik van uw deelauto gevolgen heeft gehad voor het reizen met andere vervoermiddelen?	x	x
Zou u een auto kopen als u niet was gaan autodelen?	x	x
Hoe vaak heeft u in de afgelopen twaalf maanden uw auto verhuurd aan derden?	x	
Hoe vaak heeft u in de afgelopen twaalf maanden uw auto uitgeleend aan bekenden?	x	
Via welke organisatie verhuurt u uw auto?	x	
Wat is de belangrijkste reden dat u voor <organisatie> heeft gekozen?	x	
In welk jaar heeft u voor het eerst uw auto ter verhuur aangeboden?	x	
Wat is de belangrijkste reden dat u uw auto verhuurt?	x	
Als u uw auto niet zou verhuren, zou dat een reden zijn om hem weg te doen?	x	
Hoe vaak heeft u in 2013 uw auto verhuurd?	x	
Wat vindt u van het aantal keer dat uw auto wordt verhuurd?	x	
Verhuurt u uw auto vaak aan dezelfde personen?	x	
Vindt u het belangrijk dat u de persoon kent aan wie u uw auto verhuurt?	x	
Als u geen deelauto had gebruikt, had u wellicht een van uw auto? gebruikt voor de betreffende autoritten …? --> Welk merk		x
Welk bouwjaar?		x
Welke brandstof?		x
Hoeveel ritten met een deelauto heeft u dit jaar gemaakt?		x
En hoeveel verschillende deelauto s heeft u bij deze ritten gebruikt?		x
Hoeveel kilometer per jaar reed u als bestuurder van een auto voordat u gebruik maakte van een deelauto?		x
Hoeveel kilometer per jaar rijdt u nu als bestuurder van een auto.		x
Vraag 500: En hoeveel kilometer per jaar rijdt u als bestuurder van een deelauto?		x
Blok potentiële autodelers		
Heeft u zich al verdiept in de mogelijkheden van autodelen?	x	
Hoe heeft u zich verdiept?	x	
Hadden deze personen zelf ervaring met autodelen?	x	
In welke mate was het voor u makkelijk of juist moeilijk om er achter te komen wat de specifieke voordelen van de verschillende organisaties zijn?	x	
Waarom zou u wel eens gebruik willen maken voor <deze vorm> en niet voor <andere vorm>	x	
Wat is de belangrijkste reden dat u nog niet aan autodelen doet?	x	
Onder welke omstandigheden zou u wel aan autodelen gaat doen?	x	
Wat weerhoudt u van het verhuren van uw eigen auto?	x	
Algemene panel info		
Sekse	x	x
Leeftijd	x	x
Gezinsgrootte	x	x
Gezinscyclus	x	x
Bruto jaarinkomen huishouden	x	x
Hoogst voltooide opleiding	x	x
Sociale klasse (opleiding en beroep)	x	x
Stedelijkheid (gemeenteniveau)	x	x
Provincie	x	x
Leeftijd	x	x
Inkomen	x	x
Gemeente	x	x

G. Questions to carsharing participation in Dutch

Vragen naar deelauto gebruik

Q16 Heeft u in de afgelopen 12 maanden een auto gehuurd van een organisatie? Of bent u van plan dit de komende 12 maanden te gaan doen?

- ☐ Ja, ik heb de afgelopen 12 maanden een auto gehuurd van een organisatie
- ☐ Nee, ik heb de afgelopen 12 maanden geen auto gehuurd via een organisatie, maar ik ben wel van plan om dit de komende 12 maanden te doen
- ☐ Nee, ik heb de afgelopen 12 maanden geen auto gehuurd via een organisatie, en ben dit de komende 12 maanden ook niet van plan

Q19 Kunt u in onderstaand schema aangeven hoe vaak en met welke vervoermiddelen u reist?

	Nooit	1-2 dagen per jaar	...
Een huurauto (bv. via Hertz)	☐	☐	☐
Een auto die u huurt via een deelorganisatie als Greenwheels	☐	☐	☐
Een auto die u van een particulier huurt, maar wel via een bemiddelende organisatie (zoals SnappCar)	☐	☐	☐
Een poolauto die uw werkgever ter beschikking stelt	☐	☐	☐
...	☐	☐	☐

Q24 Bij welke van onderstaande aanbieders heeft u een deelauto gehuurd? (meerdere antwoorden mogelijk)

**(Vraag alleen gesteld wanneer er 'Ja' is geantwoord op vraag Q16)*

- ☐ SnappCar
- ☐ Mobilitymix
- ☐ Greenwheels
- ☐ MyWheels
- ☐ ConnectCar
- ☐ Car2go
- ☐ WeGo
- ☐ Anders, namelijk…
- ☐ Geen

H. Conspectus of more advanced logit models for the modelling of car ownership and round-trip carsharing participation

During this study, the choice structure for car ownership and round-trip carsharing participation is represented by an MNL model. It is however acknowledged that an MNL model does not account for unobserved correlations between the alternatives and therefore other logit models might be better suitable. In this Appendix, first a short overview is given of the correlations that are expected to exist between the alternatives, after which various logit models are discussed.

The following correlations are expected between the alternatives:

- Correlation between the alternatives that include carsharing (0rt;1rt;2+rt - 0n;1n;2n;3+n)
  Households that do not participate in carsharing are expected to share an aversion towards carsharing. Households with 2 cars are expected to have more in common with households with 1 or 3 cars than with household that have an additional carsharing membership.
- Correlation between the car ownership alternatives (1rt; 2+rt; 1n; 2n; 3+n - 0n; 0rt;)
  In the motivations of people with only a carsharing membership, often reluctance to car ownership is mentioned. It is expected that households that do not participate in a carsharing program and do not own a car, share a similar reluctance to car ownership.
- Correlation between alternatives with the same number of owned cars
  Households that own one car (1n) are expected to have more in common with households that own one car with a carsharing membership (1rt) than to households than own multiple cars with a carsharing membership (2+rt).
- Correlation between alternatives that own multiple cars (2n; 2+rt; 3+n – 0n, 0rt, 1n, 1rt).
  Last, a correlation might exist between all households that own multiple cars. The correlation is questioned due to outcomes of earlier studies towards car ownership: if such a correlation exists, it would be expected that ordered logit models are more representative to the underlying choice process than unordered models. An extensive study, in which both ordered logit models and multinomial logit models for car ownership were compared, showed however that unordered choice mechanisms (MNL) more closely represent the true underlying choice process (Bhat & Pulugurta, 1998).

A MNL model does not account for unobserved correlations between alternatives and thus fall short. A nested structure might be a solution, but then compromises should be made: one cannot make a nest for both carsharing and car ownership, because there are overlapping alternatives. From a theoretical point of view, therefore a cross-nested structure is considered as the best representation of the actual choice structure, see also Figure 26. In this way, one can account for both correlations for car ownership and carsharing membership.

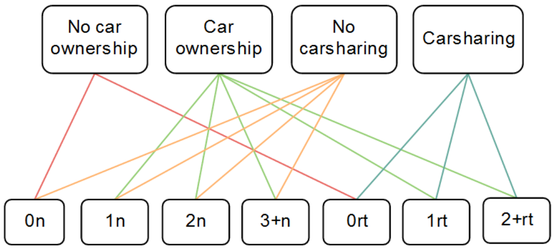


FIGURE 26: PROPOSED MODEL STRUCTURE FOR MODULE 1: CAR OWNERSHIP AND ROUND-TRIP CARSHARING MEMBERSHIP

Empirical modelling studies should be conducted to determine whether the addition of extra nests for alternatives with the same number of owned cars, or for alternatives that include multiple owned cars, give better results.

It should be emphasized that the cross-nested model structure is considered the best structure, only from a theoretical point of view. From a practical point of view, one might still consider a regular nested structure, because this requires fewer observations. Moreover, cross-nested models can only be estimated with a limited number of estimation software packages and the estimation process is more time-consuming than for regular nested models.

I. Definition of available variables for empirical modelling

Variable code	N	*Variable*	*Measurement*	*Variable definition*
aware	1694	Dummy: Aware of carsharing	Nominal	1 = Aware; 0 = Unaware
social	1694	Dummy: Presence of carsharers in environment	Nominal	1 = Yes; 0 = No/Unknown
agehohh	1311	Age partner of breadwinner	Ordinal	<35; 35-39; 40-49; 50-64; 65+
hhsize	1694	Household size	Interval	1; 2; 3; 4; 5; 6+
education	1694	Education level of respondent	Ordinal	1 = No education; 2 = primary education; 3 = LBO/VVBO/VMBO (kader)/MBO 1; 4 = MAVO/first three years of HAVO and VWO, VMBO (theoretisch); 5 = MBO 2,3,4 or MBO old structure; 6 = HAVO/VWO or first year HBO/WO; 7 = HBO/WO bachelor; 8 = HBO/WO Master
urblvl	1694	Urbanization degree municipality	Ordinal	1; 2; 3; 4; 5
hhtype	1694	Household composition	Nominal	Single household; adult household with multiple persons; household with children
nradults	1694*	Number of adults*	Scale	
nrkids	1694*	Number of children*	Scale	
grinchh	1344	Gross household income	Scale	
densrt	1549	Density of round trip cars	Scale	
supplyrt	1549	Supply of round-trip cars in municipality	Scale	
pcosts	1549	Average price for short stay parking in the municipality	Scale	
greenvot	1549	Percentage of green party voters in municipality	Scale	
polgeninfo	1549	Municipality offers carsharing information on website	Nominal	1 = Yes; 0 = No
ptacc	1549	Accessibility indicator public transport	Scale	
rnacc	1549	Accessibility indicator car transport	Scale	

*The number of adults and the number of children are not implicitly asked for in the survey, but can be derived from the household size and the household composition, albeit with a number of assumptions that are described in Appendix M.

J. Determination of population shares and ASC correction

Model B1 is estimated on a choice-based sample, which has led to an overestimation of the ASC's for the carsharing alternatives. Therefore, first the ASC's have to be corrected, according to the methodology as described in Paragraph 5.2.2. For the ASC correction, a representative sample of the population is needed and therefore a weighted version of the TNS NIPO sample is used. The weights solely correct for the oversampling of carsharing participants and it is thus assumed that no other oversampling is present.

The determination of the weights is shown in Table 41. The combination of round 1 and round 2 is used to approximate the population shares for three groups: round-trip carsharing, other forms of carsharing and no carsharing. It is hereby assumed that all P2P and B2C carsharing participants are equally oversampled and that all households not participating in carsharing are equally under sampled. This assumption is based on the fact that the sample is (apart from the choice-based selection) randomly selected from the TNS NIPO panel, which is stated to be representative for the complete population.

Then, the latter two groups are combined to determine the total share of people who are not participating in round-trip carsharing. The weights are based on the approximated population shares and chosen such that the average weight is 1.

Model B1 is then applied to the weighted sample and based on the application results, the ASC's of the carsharing alternatives are iteratively adapted until the share of round-trip carsharing matched the approximated population shares. As a result, the ASC's for the roundtrip carsharing participation alternatives (0rt; 1+rt) are adjusted with -2.203.

TABLE 41: WEIGHT DETERMINATION FOR MODEL APPLICATION

		No round-trip carsharing		
	Round-trip carsharing participants	Other carsharing participants	No carsharing participants	Total
Observations in auxiliary sample (round 1)	1,425		73,644	75,069
Approximated population shares based on round 1	1.90%		98.10%	100%
Sample distribution (round 2, cleared from untrusted records)	169	93	1,525	1,787
Approximated population shares based on round 1 & 2	1.22%	0.67%	98.10%	100%
	1.22%	98.78%		100%
Applied weights	**0.124**	**1.095**		**1**

K. VARIATIONS ON THE FULL MODEL

In this Appendix two variations on the full model are estimated. A description of the models is provided in the overview below:

Model name	Shown in…	Difference with full model
Full model without Amsterdam	Table 42	In this model, the dummy variable for living in Amsterdam is missing. In the estimation results, the colours indicate to what extent the full model is changed as a result of the addition of the dummy variable.
Full model for Likelihood Ratio Test	Table 43	In this model, the variable specification is altered, such that the best possible model is nested in this model. As a result, the household size is excluded and replaced by the number of adults and the number of children. Moreover, various age- and urbanization degree categories are combined.

TABLE 42: FULL MODEL WITHOUT AMSTERDAM (N=1549 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). REFERENCE: 0N (NO ROUNDTRIP CARSHARING, NO CAR). SIGNIFICANT PARAMETERS (P<0.05, T-STATISTIC >1.96) ARE MARKED IN BOLD. THE COLOUR INDICATES TO WHAT EXTENT THE COEFFICIENTS DIFFER FROM THE FULL MODEL. RESPONDENTS AWARE OF CARSHARING (1267) ARE FACED WITH THE COMPLETE CHOICE SET, FOR THE OTHER HOUSEHOLDS (282) ONLY THE ALTERNATIVES 0N, 1N AND 2+N ARE AVAILABLE.

Number of observations	1549
Final log likelihood	-1395.6
Degrees of Freedom	79
Rho²(0)	0.406

	1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.
ASC*	3.488	*1.7*	-1.273	*-0.6*	-5.869	*-1.8*	-3.792	*-0.9*
Household size	0.104	*0.5*	0.536	*0.5*	-0.090	*-0.3*	**0.751**	*2.7*
Dummy: Single household	**-1.805**	*-2.9*	**-2.243**	*-2.2*	-1.455	*-1.6*	-1.209	*-1.2*
Dummy: Adult household multiple persons	**-1.221**	*-2.7*	-0.243	*-0.2*	-0.960	*-1.5*	-0.785	*-1.1*
ref: household with kids								
Dummy: Partner breadwinner of household <35	**-1.653**	*-5.6*	0.236	*0.2*	0.957	*1.7*	-0.034	*-0.1*
Dummy: Partner breadwinner of household 35-39	**-1.639**	*-4.4*	-0.169	*-0.2*	0.475	*0.7*	**-2.534**	*-2.1*
Dummy: Partner breadwinner of household 40-49	**-0.927**	*-3.1*	0.671	*0.7*	0.751	*1.3*	-0.470	*-0.7*
Dummy: Partner breadwinner of household 50-64	**-0.523**	*-2.1*	0.668	*0.7*	**1.090**	*2.1*	-0.203	*-0.3*
ref: Partner breadwinner 65+								
Gross household income (x 100.000)	**1.802**	*3.5*	**3.413**	*3.4*	**2.366**	*3.8*	**3.040**	*4.5*
Dummy: income unknown	**0.786**	*2.7*	**1.978**	*2.0*	0.799	*1.8*	**1.200**	*2.0*
Dummy: Urbanization degree 1	-0.548	*-0.9*	-1.461	*-1.5*	0.802	*1.2*	-0.077	*-0.1*
Dummy: Urbanization degree 2	-0.442	*-0.8*	-0.938	*-0.9*	0.414	*0.7*	-0.172	*-0.3*
Dummy: Urbanization degree 3	-0.444	*-0.8*	-0.737	*-0.7*				
Dummy: Urbanization degree 4	-0.292	*-0.5*	-0.263	*-0.3*				
ref: urbanization degree 5								
Dummy: HBO+ education	0.194	*1.0*	0.284	*0.3*	0.046	*0.2*	**1.012**	*2.4*
Indicator public transport accessibility	-0.008	*-1.1*	-0.016	*0.0*	0.012	*0.9*	-0.002	*-0.1*
Indicator car transport accessibility	0.003	*0.1*	0.008	*0.0*	-0.030	*-1.1*	0.004	*0.1*
Percentage of green votes in municipality	-2.901	*-0.9*	0.676	*0.7*	9.467	*1.4*	-3.129	*-0.4*
Average price for short stay parking in the municipality	**-0.523**	*-2.3*	-0.860	*-0.9*			-0.242	*-0.3*
Dummy: Living in Amsterdam	-		-		-		-	
Total number of round-trip cars in municipality					0.000	*0.1*	0.001	*0.3*
Density of round-trip cars in municipality					-0.687	*-1.0*	-0.594	*-0.6*
Dummy: carsharing participants in social environment					**2.843**	*9.5*	**2.994**	*7.2*
Dummy: Carsharing information available on municipality website					0.287	*0.7*	0.376	*0.8*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

Change in coefficients compared to the full model

Coefficient changed with factor >1
Coefficient changed with factor 0.5 to 1
Coefficient changed with factor 0.3 to 0.5

TABLE 43: FULL MODEL FOR LIKELIHOOD RATIO TEST (N=1549 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). REFERENCE: 0N (NO ROUNDTRIP CARSHARING, NO CAR). SIGNIFICANT PARAMETERS (P<0.05, T-STATISTIC >1.96) ARE MARKED IN BOLD. RESPONDENTS AWARE OF CARSHARING (1267) ARE FACED WITH THE COMPLETE CHOICE SET, FOR THE OTHER HOUSEHOLDS (282) ONLY THE ALTERNATIVES 0N, 1N AND 2+N ARE AVAILABLE.

Number of observations	1549
Final log likelihood	-1402.3
Degrees of Freedom	68
Rho²(0)	0.403

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
ASC*			1.859	*1.0*	-2.842	*-1.3*	**-8.279**	*-2.7*	-6.153	*-1.5*
Number of adults in the household			**0.366**	*2.4*	1.283	*1.3*	0.307	*1.2*	**1.398**	*5.3*
Number of children in the household			**1.040**	*4.7*	1.148	*1.1*	0.519	*1.9*	**1.299**	*4.8*
Dummy: Partner breadwinner of household <35					-0.009	*0.0*			0.057	*0.1*
Dummy: Partner breadwinner of household 35-39					-0.329	*-0.3*			-2.223	*-1.9*
Dummy: Partner breadwinner of household 40-49			**-1.014**	*-3.9*					-0.279	*-0.4*
Dummy: Partner breadwinner of household 50-64			**-0.619**	*-2.6*					-0.304	*-0.5*
Dummy: Partner breadwinner of household 18-39			**-1.695**	*-6.4*						
Dummy: Partner breadwinner of household 40-64					0.352	*0.4*				
Dummy: Partner breadwinner of household 18-64							0.879	*1.8*		
ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.100**	*4.1*	**3.823**	*3.8*	**2.570**	*4.1*	**3.260**	*4.9*
Dummy: income unknown			**0.892**	*3.1*	**2.110**	*2.1*	0.860	*1.9*	1.324	*2.2*
Dummy: Urbanization degree 1			-0.925	*-1.5*	-1.672	*-1.7*			-0.187	*-0.2*
Dummy: Urbanization degree 1 & 2							0.665	*1.3*		
Dummy: Urbanization degree 2									-0.111	*-0.2*
Dummy: Urbanization degree 2 & 3			-0.636	*-1.2*	-0.983	*-1.0*				
Dummy: Urbanization degree 4			-0.327	*-0.6*	-0.282	*-0.3*				
ref: urbanization degree 5										
Dummy: HBO+ education			0.131	*0.7*	0.233	*0.2*	0.024	*0.1*	**1.045**	*2.4*
Indicator public transport accessibility			-0.007	*-0.9*	-0.014	*0.0*	0.011	*0.8*	0.000	*0.0*
Indicator car transport accessibility			0.006	*0.3*	0.011	*0.0*	-0.034	*-1.2*	0.004	*0.1*
Percentage of green votes in municipality			-1.825	*-0.5*	0.052	*0.1*	9.097	*1.3*	-2.453	*-0.3*
Average price for short stay parking in the municipality			0.074	*0.2*	-0.284	*-0.3*			0.203	*0.3*
Dummy: Living in Amsterdam	**1.006**	*2.0*								
Total number of round-trip cars in municipality							0.001	*0.3*	0.001	*0.3*
Density of round-trip cars in municipality							-0.504	*-0.8*	-0.535	*-0.6*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

L. Correlations in the enriched sample data

The table below shows the correlations that exist among the variables in the enriched sample data. The colour shows the strength of the correlation; the more towards red, the stronger the correlation. To mark whether a correlation is significant, the number are underlined (p<0.05) or **bold** (p<0.005).

	aware	social	agehohh	*hhsize*	education	urblvl	hhtype	nradults	nrkids	grinchh	densrt	supplyrt	Adam	pcosts	greenvot	polgeninfo	ptacc	rnacc
aware	1.00																	
social	**0.22**	1.00																
agehohh	-0.01	**0.08**	1.00															
hhsize	**0.10**	**0.06**	**-0.10**	*1.00*														
education	**-0.24**	**-0.25**	**-0.22**	***-0.06***	1.00													
urblvl	**0.10**	**0.20**	**0.13**	***0.17***	**-0.22**	1.00												
hhtype	**0.08**	**0.13**	**0.29**	***0.75***	**-0.15**	**0.20**	1.00											
nradults	**0.09**	**0.09**	**0.16**	***0.66***	**-0.15**	**0.16**	**0.58**	1.00										
nrkids	0.06	0.01	**-0.27**	***0.79***	0.03	**0.09**	**0.53**	0.06	1.00									
grinchh	-0.06	-0.07	0.05	***0.24***	**0.25**	-0.03	**0.27**	**0.26**	**0.11**	1.00								
densrt	**-0.13**	**-0.22**	**-0.08**	***-0.19***	**0.21**	**-0.64**	**-0.23**	**-0.16**	**-0.12**	0.04	1.00							
supplyrt	**-0.12**	**-0.20**	**-0.07**	***-0.18***	**0.19**	**-0.59**	**-0.22**	**-0.15**	**-0.11**	0.03	**0.99**	1.00						
Adam	**-0.12**	**-0.19**	-0.06	***-0.17***	**0.18**	**-0.55**	**-0.21**	**-0.14**	**-0.11**	0.02	**0.97**	**1.00**	1.00					
pcosts	**-0.13**	**-0.22**	**-0.07**	***-0.19***	**0.21**	**-0.72**	**-0.23**	**-0.16**	**-0.12**	0.03	**0.94**	**0.93**	**0.92**	1.00				
greenvot	**-0.14**	**-0.27**	**-0.10**	***-0.21***	**0.26**	**-0.76**	**-0.24**	**-0.19**	**-0.12**	0.06	**0.84**	**0.78**	**0.74**	**0.82**	1.00			
polgeninfo	**-0.13**	**-0.23**	**-0.09**	***-0.15***	**0.18**	**-0.68**	**-0.19**	**-0.17**	-0.07	0.00	**0.64**	**0.60**	**0.57**	**0.65**	**0.73**	1.00		
ptacc	0.07	**0.16**	**0.10**	***0.12***	**-0.17**	**0.57**	**0.15**	**0.15**	0.04	-0.01	**-0.40**	**-0.35**	**-0.33**	**-0.39**	**-0.55**	**-0.47**	1.00	
rnacc	-0.01	-0.04	-0.04	*0.01*	0.01	**-0.18**	-0.04	-0.03	0.04	0.01	**0.17**	**0.17**	**0.17**	**0.21**	**0.17**	**0.13**	**0.07**	1.00

Bold: Significant <0.005
Underlined: Significant <0.05

M. Deduction of number of children and number of adults

Table 44 presents the assumed number of adults and number of children for various household sizes and household types. In order to determine the number of children and the number of adults, information of two variables is combined: household size and household composition. In the variable of household composition, it is denoted whether children are present or not. The household size gives information on the number of household members up to 6 or more persons.

TABLE 44: ASSUMED NUMBER OF ADULTS AND NUMBER OF CHILDREN BASED ON HOUSEHOLD TYPE AND HOUSEHOLD SIZE

	Adult household		Household with children	
Household size	# of adults	# of children	# of adults	# of children
1	1	-	-	-
2	2	-	1	1
3	3	-	1.83	1.17
4	4	-	1.95	2.05
5	5	-	2	3
6+	6+	-	2	4+

In the case of households with children, the number of adults and children are unknown (except when the household size equals 2), and therefore assumptions had to be made. To do so, national statistics on the household distribution in 2014 are consulted (CBS, 2016), see also Table 45. Based on the data, it was found that three person households with children consist on average of 1.83 adults and 1.17 children. In the same way, the number of adults and number of children in a four person household are computed. In the latter case, all households with one adult and three or more children are assumed to be four person households. From 5 persons onwards, it is assumed that 2 adults are present.

TABLE 45: DISTRIBUTION OF HOUSEHOLDS WITH CHILDREN IN THE NETHERLANDS IN 2014 (CBS, 2016).

Households with children Year: 2014	Households with 2 adults			Households with 1 adult		
Household size	3	4	5+	2	3	4+
Number of children	1	2	3+	1	2	3+
Number of households	754,517	919,824	359,657	331,653	156,324	47,893

N. Alternatives tested in the empirical modelling estimation

This appendix shows the various alternatives that are empirically tested for combinations of the highly correlating variables 'Round-trip supply', 'Public transport access', and 'Urbanization degree'.

TABLE 46: OVERVIEW OF TESTED ALTERNATIVES

Alternative		
1	Round-trip supply and public transport access	
2	Urbanization degree and public transport access	2a: PT-accessibility parameter for all alternatives except reference alternative
		2b: PT accessibility parameters only for 1n and 2n
3	Urbanization degree and round-trip supply	3a: Supply of round-trip cars linear
		3b: Dummy for supply >1
		3c: Dummy for supply >10
		3d: Dummy for supply >10 and adapted urbanization degree parameters
4	Urbanization degree only	

TABLE 47: ALTERNATIVE 1: ROUND-TRIP SUPPLY AND PUBLIC TRANSPORT ACCESS

Number of observations	1549
Final log likelihood	-1423.1
Degrees of Freedom	35
Rho²(0)	0.394

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			-0.028	*0.0*	**-6.145**	*-8.8*	**-4.798**	*-3.6*	**-6.847**	*-4.9*
Dummy: living in Amsterdam	**1.441**	*7.7*								
Number of adults in the household			**0.348**	*2.3*	**1.250**	*7.6*	0.300	*1.2*	**1.399**	*5.5*
Number of children in the household			**1.029**	*4.7*	**1.138**	*5.2*	**0.603**	*2.2*	**1.245**	*4.9*
Dummy: Partner breadwinner <40			**-1.609**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.946**	*-4.2*						
Dummy: Age partner breadwinner 50-64			**-0.554**	*-2.9*						
Dummy: Age partner breadwinner 40-64					**0.459**	*2.4*				
Dummy: Age partner breadwinner 18-64							**0.920**	*2.0*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.089**	*4.3*	**3.709**	*7.1*	**2.580**	*4.3*	**3.147**	*4.9*
Dummy: income unknown			**0.859**	*3.0*	**1.985**	*6.1*	**0.905**	*2.0*	**1.165**	*2.0*
Dummy: HBO+ education									**1.009**	*2.6*
Dummy: Carsharing participants in social environment							**2.744**	*9.5*	**3.152**	*7.7*
Public transport accessibility			**-0.012**	*-2.0*	**-0.026**	*-4.2*	0.001	*0.1*	0.000	*0.0*
Dummy: Round-trip shared car supply >10							**1.530**	*4.0*	**-0.760**	*-2.0*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 48: ALTERNATIVE 2A: PT-ACCESSIBILITY PARAMETER FOR ALL ALTERNATIVES EXCEPT REFERENCE ALTERNATIVE

Number of observations	1549
Final log likelihood	-1414.9
Degrees of Freedom	39
Rho²(0)	0.398

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			0.887	*1.1*	**-3.955**	*-4.5*	**-3.721**	*-2.9*	**-7.395**	*-5.5*
Dummy: living in Amsterdam	**1.175**	*5.2*								
Number of adults in the household			**0.352**	*2.4*	**1.254**	*7.6*	0.263	*1.1*	**1.406**	*5.6*
Number of children in the household			**1.026**	*4.7*	**1.111**	*5.1*	**0.586**	*2.2*	**1.228**	*4.9*
Dummy: Partner breadwinner <40			**-1.611**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.981**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.561**	*-2.9*						
Dummy: Age partner breadwinner 40-64					**0.410**	*2.1*				
Dummy: Age partner breadwinner 18-64							**0.975**	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.149**	*4.4*	**3.895**	*7.4*	**2.531**	*4.2*	**3.180**	*4.9*
Dummy: income unknown			**0.903**	*3.2*	**2.113**	*6.4*	0.786	*1.8*	**1.228**	*2.1*
Dummy: HBO+ education									**0.897**	*2.3*
Dummy: Carsharing participants in social environment							**2.851**	*9.9*	**3.053**	*7.5*
Dummy: Urbanization degree 1			**-0.734**	*-2.1*	**-1.794**	*-4.6*			-0.648	*-1.7*
Dummy: Urbanization degree 1 and 2							**0.881**	*2.1*		
Dummy: Urbanization degree 2 and 3			**-0.506**	*-1.7*	**-0.938**	*-2.9*				
Ref: Urbanization degree 4 and 5										
Public transport accessibility			-0.007	*-1.1*	-0.013	*-1.9*	0.010	*0.9*	-0.005	*-0.4*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 49: ALTERNATIVE 2B: PT ACCESSIBILITY PARAMETERS ONLY FOR 1N AND 2N

Number of observations	1549
Final log likelihood	-1415.5
Degrees of Freedom	37
Rho²(0)	0.397

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			0.751	*1.0*	**-4.081**	*-5.1*	**-4.668**	*-6.2*	**-6.927**	*-9.2*
Dummy: living in Amsterdam	**1.152**	*5.1*								
Number of adults in the household			**0.351**	*2.4*	**1.253**	*7.6*	0.246	*1.0*	**1.415**	*5.6*
Number of children in the household			**1.025**	*4.7*	**1.110**	*5.1*	**0.596**	*2.2*	**1.219**	*4.8*
Dummy: Partner breadwinner <40			**-1.610**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.979**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.558**	*-2.9*						
Dummy: Age partner breadwinner 40-64					**0.412**	*2.1*				
Dummy: Age partner breadwinner 18-64							**0.986**	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.149**	*4.4*	**3.896**	*7.4*	**2.521**	*4.2*	**3.200**	*4.9*
Dummy: income unknown			**0.902**	*3.1*	**2.112**	*6.4*	0.786	*1.8*	**1.245**	*2.1*
Dummy: HBO+ education									**0.872**	*2.3*
Dummy: Carsharing participants in social environment							**2.852**	*9.9*	**3.050**	*7.5*
Dummy: Urbanization degree 1			**-0.719**	*-2.1*	**-1.781**	*-4.6*			-0.726	*-1.9*
Dummy: Urbanization degree 1 and 2							**0.971**	*2.4*		
Dummy: Urbanization degree 2 and 3			-0.476	*-1.6*	**-0.909**	*-2.8*				
Ref: Urbanization degree 4 and 5										
Public transport accessibility			-0.008	*-1.5*	**-0.014**	*-2.4*				

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 50: ALTERNATIVE 3A: SUPPLY OF ROUND-TRIP CARS LINEAR

Number of observations	1549
Final log likelihood	-1417.9
Degrees of Freedom	37
Rho²(0)	0.396

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.676**	*4.4*	**-2.451**	*-5.7*	**-4.675**	*-6.2*	**-6.890**	*-9.1*
Dummy: living in Amsterdam	**1.080**	*4.4*								
Number of adults in the household			**0.352**	*2.4*	**1.262**	*7.6*	0.225	*0.9*	**1.400**	*5.6*
Number of children in the household			**1.018**	*4.7*	**1.100**	*5.1*	**0.578**	*2.1*	**1.208**	*4.8*
Dummy: Partner breadwinner <40			**-1.603**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.983**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.552**	*-2.8*						
Dummy: Age partner breadwinner 40-64					**0.413**	*2.1*				
Dummy: Age partner breadwinner 18-64							**1.015**	*2.2*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.165**	*4.4*	**3.894**	*7.4*	**2.540**	*4.2*	**3.190**	*4.9*
Dummy: income unknown			**0.915**	*3.2*	**2.128**	*6.4*	0.810	*1.8*	**1.238**	*2.1*
Dummy: HBO+ education									**0.911**	*2.4*
Dummy: Carsharing participants in social environment							**2.896**	*10.0*	**3.070**	*7.6*
Dummy: Urbanization degree 1			**-1.031**	*-3.1*	**-2.289**	*-6.3*			-0.549	*-1.1*
Dummy: Urbanization degree 1 and 2							**1.066**	*2.6*		
Dummy: Urbanization degree 2 and 3			**-0.652**	*-2.3*	**-1.211**	*-4.1*				
Ref: Urbanization degree 4 and 5										
Round-trip shared car supply							-0.034	*-1.0*	-0.047	*-0.7*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 51: ALTERNATIVE 3B: DUMMY FOR SUPPLY >1

Number of observations	1549
Final log likelihood	-1415.3
Degrees of Freedom	37
Rho²(0)	0.397

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.546**	*4.0*	**-2.589**	*-6.0*	**-5.566**	*-6.2*	**-7.223**	*-8.8*
Dummy: living in Amsterdam	**1.237**	*5.5*								
Number of adults in the household			**0.355**	*2.4*	**1.266**	*7.7*	0.271	*1.1*	**1.427**	*5.7*
Number of children in the household			**1.027**	*4.7*	**1.109**	*5.1*	**0.588**	*2.2*	**1.222**	*4.8*
Dummy: Partner breadwinner <40			**-1.608**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.981**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.552**	*-2.8*						
Dummy: Age partner breadwinner 40-64					**0.417**	*2.1*				
Dummy: Age partner breadwinner 18-64							**0.965**	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.155**	*4.4*	**3.882**	*7.4*	**2.535**	*4.2*	**3.138**	*4.8*
Dummy: income unknown			**0.906**	*3.2*	**2.117**	*6.4*	**0.840**	*1.9*	**1.217**	*2.0*
Dummy: HBO+ education									**0.894**	*2.3*
Dummy: Carsharing participants in social environment							**2.792**	*9.7*	**3.002**	*7.4*
Dummy: Urbanization degree 1			**-0.776**	*-2.4*	**-2.027**	*-5.7*			**-0.771**	*-2.0*
Dummy: Urbanization degree 1 and 2							0.555	*1.3*		
Dummy: Urbanization degree 2 and 3			-0.532	*-1.9*	**-1.087**	*-3.6*				
Ref: Urbanization degree 4 and 5										
Dummy: Round-trip shared car supply >1							**1.426**	*2.2*	0.461	*1.0*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 52: ALTERNATIVE 3C: DUMMY FOR SUPPLY >10

Number of observations	1549									
Final log likelihood	-1411.2									
Degrees of Freedom	37									
Rho²(0)	0.399									
	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.688**	*4.4*	**-2.448**	*-5.7*	**-4.850**	*-6.3*	**-6.776**	*-8.9*
Dummy: living in Amsterdam	**1.291**	*5.6*								
Number of adults in the household			**0.355**	*2.4*	**1.267**	*7.7*	0.277	*1.2*	**1.398**	*5.5*
Number of children in the household			**1.028**	*4.7*	**1.111**	*5.1*	**0.619**	*2.3*	**1.242**	*4.9*
Dummy: Partner breadwinner <40			**-1.616**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.991**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.567**	*-2.9*						
Dummy: Age partner breadwinner 40-64					**0.409**	*2.1*				
Dummy: Age partner breadwinner 18-64							0.912	*1.9*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.161**	*4.4*	**3.886**	*7.4*	**2.545**	*4.2*	**3.125**	*4.8*
Dummy: income unknown			**0.905**	*3.2*	**2.113**	*6.4*	**0.879**	*2.0*	**1.130**	*1.9*
Dummy: HBO+ education									**1.017**	*2.6*
Dummy: Carsharing participants in social environment							**2.728**	*9.4*	**3.138**	*7.7*
Dummy: Urbanization degree 1			**-0.859**	*-2.6*	**-2.114**	*-5.9*			0.120	*0.2*
Dummy: Urbanization degree 1 and 2							0.224	*0.5*		
Dummy: Urbanization degree 2 and 3			**-0.717**	*-2.6*	**-1.281**	*-4.3*				
Ref: Urbanization degree 4 and 5										
Dummy: Round-trip shared car supply >10							**1.196**	*2.6*	**-1.043**	*-2.2*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 53: ALTERNATIVE 3D: 3D: DUMMY FOR SUPPLY >10 AND ADAPTED URBANIZATION DEGREE PARAMETERS

Number of observations	1549									
Final log likelihood	-1411.3									
Degrees of Freedom	35									
Rho²(0)	0.399									
	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.701**	*4.4*	**-2.436**	*-5.7*	**-4.752**	*-6.5*	**-6.759**	*-8.9*
Dummy: living in Amsterdam	**1.268**	*5.7*								
Number of adults in the household			**0.355**	*2.4*	**1.267**	*7.7*	0.278	*1.2*	**1.394**	*5.5*
Number of children in the household			**1.027**	*4.7*	**1.111**	*5.1*	**0.618**	*2.3*	**1.240**	*4.9*
Dummy: Partner breadwinner <40			**-1.615**	*-8.2*						
Dummy: Age partner breadwinner 40-49			**-0.989**	*-4.4*						
Dummy: Age partner breadwinner 50-64			**-0.566**	*-2.9*						
Dummy: Age partner breadwinner 40-64					**0.410**	*2.1*				
Dummy: Age partner breadwinner 18-64							0.906	*1.9*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.161**	*4.4*	**3.886**	*7.4*	**2.552**	*4.2*	**3.130**	*4.8*
Dummy: income unknown			**0.905**	*3.2*	**2.113**	*6.4*	**0.893**	*2.0*	1.134	*1.9*
Dummy: HBO+ education									**1.018**	*2.6*
Dummy: Carsharing participants in social environment							**2.720**	*9.4*	**3.136**	*7.7*
Dummy: Urbanization degree 1			**-0.894**	*-2.8*	**-2.150**	*-6.2*				
Dummy: Urbanization degree 2 and 3			**-0.724**	*-2.6*	**-1.288**	*-4.4*				
Ref: Urbanization degree 4 and 5										
Dummy: Round-trip shared car supply >10							**1.303**	*3.4*	**-0.980**	*-2.7*

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

TABLE 54: ALTERNATIVE 4: URBANIZATION DEGREE ONLY

Number of observations	1549
Final log likelihood	-1418.5
Degrees of Freedom	35
Rho²(0)	0.396

	0n		1n		2+n		0rt		1+rt	
Attribute	β	t-st.	β	t-st.	β	t-st.	β	t-st.	β	t-st.
Alternative specific constant*			**1.667**	*4.3*	**-2.464**	*-5.7*	**-7.23***	*-6.2*	**-9.48***	*-9.1*
Dummy: living in Amsterdam	**1.192**	*5.4*								
Number of adults in the household			**0.353**	*2.4*	**1.263**	*7.6*	0.236	*1.0*	**1.407**	*5.6*
Number of children in the household			**1.023**	*4.7*	**1.106**	*5.1*	**0.602**	*2.2*	**1.226**	*4.9*
Dummy: Partner breadwinner <40			**-1.610**	*-8.2*			**0.999**[B]	*2.1*		
Dummy: Age partner breadwinner 40-49			**-0.982**	*-4.4*	**0.416**[A]	*2.1*	**0.999**[B]	*2.1*		
Dummy: Age partner breadwinner 50-64			**-0.553**	*-2.8*	**0.416**[A]	*2.1*	**0.999**[B]	*2.1*		
Ref: Partner breadwinner 65+										
Gross household income (x 100.000)			**2.165**	*4.4*	**3.893**	*7.4*	**2.512**	*4.2*	**3.172**	*4.9*
Dummy: income unknown			**0.914**	*3.2*	**2.125**	*6.4*	**0.791**	*1.8*	**1.227**	*2.1*
Dummy: HBO+ education									**0.902**	*2.4*
Dummy: Carsharing participants in social environment							**2.856**	*10.0*	**3.052**	*7.5*
Dummy: Urbanization degree 1			**-0.938**	*-3.0*	**-2.194**	*-6.3*	**0.988**[E]	*2.5*	**-0.707**	*-1.9*
Dummy: Urbanization degree 2			**-0.663**[C]	*-2.4*	**-1.223**[D]	*-4.1*	**0.988**[E]	*2.5*		
Dummy: Urbanization degree 3			**-0.663**[C]	*-2.4*	**-1.223**[D]	*-4.1*				
Ref: Urbanization degree 4 and 5										

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

O. Model results of best possible model, re-estimated on a larger set of observations.

This Appendix presents the estimation results of a re-estimation of the best possible model, now based on a larger set of observation. The data originates from the same source (TNS NIPO sample), but now also the observations of which the municipality is unknown, are used for the estimation. The renewed sample distribution is shown in Table 55, the model results are presented in Table 56.

In the re-estimation of the best possible model, an extra dummy variable is estimated for all people of whom it is unknown if they lived in Amsterdam at the time the survey was conducted (36 in total). For the other 109 added observations, the municipality is also unknown, but based on the province and urbanization degree of the municipality, one can conclude that they were not living in Amsterdam.

TABLE 55: DISTRIBUTION OF MODEL ALTERNATIVES IN SAMPLE DATA, INCL. OBSERVATIONS OF WHICH MUNICIPALITY IS UNKNOWN.

	Entire sample	No round-trip carsharing membership			Round-trip carsharing membership	
		Households with no car	Households with 1 car	Households with 2 cars	Roundtrip carsharing membership and no car	Roundtrip carsharing membership and 1 car
		0n	1n	2+n	0rt	1+rt
n	1694	227	907	391	111	58

The parameters of the re-estimated model as presented in Table 56 more or less equal the earlier estimated parameters of the best possible model. A notable difference is the reduction of all parameters that are related to the number of children in the household. This means that the added observations either count relatively more observations of households with children in the 0n alternative, or relatively fewer observations of households with (multiple) children in the other alternatives.

TABLE 56: RE-ESTIMATION OF BEST POSSIBLE MODEL (N=1694 – HOUSEHOLDS WITH DRIVING LICENCE HOLDERS ONLY). SIGNIFICANT PARAMETERS (AT 95% CONFIDENCE INTERVAL) ARE MARKED IN BOLD. RESPONDENTS AWARE OF CARSHARING (1390) WERE GIVEN THE COMPLETE CHOICE SET, FOR THE OTHER HOUSEHOLDS (304) ONLY THE ALTERNATIVES 0N, 1N AND 2+N WERE AVAILABLE.

Number of observations	1694				
Final log likelihood	-1575.3				
Degrees of Freedom	36				
Rho²(0)	0.387				
	0n	1n	2+n	0rt	1+rt
ASC*		**1.824** *5.0*	**-2.406** *-5.9*	**-4.725** *-6.6*	**-6.460** *-9.6*
Dummy: living in Amsterdam	**1.144** *5.4*				
Dummy: living in Amsterdam unknown	0.620 *1.4*				
Number of adults in the household		**0.315** *2.3*	**1.247** *7.9*	0.294 *1.3*	**1.343** *5.9*
Number of children in the household		**0.850** *4.6*	**0.997** *5.3*	0.441 *1.8*	**1.059** *4.8*
Dummy: Partner breadwinner <40		**-1.540** *-8.3*			
Dummy: Age partner breadwinner 40-49		**-0.981** *-4.6*			
Dummy: Age partner breadwinner 50-64		**-0.609** *-3.2*			
Dummy: Age partner breadwinner 40-64			**0.377** *2.1*		
Dummy: Age partner breadwinner <65				**0.978** *2.1*	
Ref: Partner breadwinner 65+					
Gross household income (x 100.000)		**2.290** *4.9*	**3.941** *7.9*	**2.501** *4.3*	**2.964** *4.6*
Dummy: income unknown		**0.851** *3.2*	**2.015** *6.5*	**0.726** *1.8*	**1.026** *1.9*
Dummy: HBO+ education					**0.820** *2.4*
Dummy: Carsharing participants in social environment				**2.908** *10.5*	**2.998** *8.2*
Dummy: Urbanization degree 1		**-1.066** *-3.6*	**-2.233** *-6.7*	**0.873**[E] *2.3*	**-0.771** *-2.2*
Dummy: Urbanization degree 2		**-0.842**[C] *-3.2*	**-1.307**[D] *-4.6*	**0.873**[E] *2.3*	
Dummy: Urbanization degree 3		**-0.842**[C] *-3.2*	**-1.307**[D] *-4.6*		
Ref: Urbanization degree 4 and 5					

*The ASC's still have to be calibrated to account for the oversampling of carsharing users.

P. Model coefficients in current car ownership model in LMS

Table 57 shows the overview of all car ownership coefficients that are used to determine car ownership in the LMS model. The table originates from the Technical Documentation of the LMS model (Rijkswaterstaat, 2017).

TABLE 57: CAR OWNERSHIP COEFFICIENTS USED IN THE LMS (RIJKSWATERSTAAT, 2017, P. 184)

Coëfficiënt	Variabele & Verklaring	i=Alternatief			
		0	1	2	3+
Car(i)	Alternatief specifieke constante		✓	✓	✓
Lic2Car(i)	Dummy-variabele met waarde 1, wanneer twee leden van het huishouden een rijbewijs bezitten		✓	✓	✓
Lic3Car(i)	Dummy-variabele met waarde 1, wanneer drie of meer leden van het huishouden een rijbewijs bezitten		✓	✓	✓
Inc(i)	$\log^{RestInc}(i)$: Restinkomen na aftrek van de kosten voor één of meer auto's		✓	✓	✓
Npers(i)	NoLic: Aantal personen in een huishouden zonder rijbewijs		✓	✓	
PD(i)_1km	Bevolkingsdichtheid van alle zones binnen één kilometer van het zonezwaartepunt		✓	✓	✓
ED(i)_1km	Arbeidsplaatsendichtheid van alle zones binnen één kilometer van het zonezwaartepunt		✓	✓	✓
ED(i)_5km	Arbeidsplaatsendichtheid van alle zones binnen vijf kilometer van het zonezwaartepunt		✓	✓	✓
Hleeft35	Dummy-variabele met waarde 1, wanneer het hoofd van het huishouden 35 jaar of ouder is	✓			
Hleeft55	Dummy-variabele met waarde 1, wanneer het hoofd van het huishouden 55 jaar of ouder is	✓			
Hleeft65	Dummy-variabele met waarde 1, wanneer het hoofd van het huishouden 65 jaar of ouder is	✓			
Hleeft80	Dummy-variabele met waarde 1, wanneer het hoofd van het huishouden 80 jaar of ouder is	✓			
NFT(i)	Aantal fulltimers in het huishouden		✓	✓	✓
NPT(i)	Aantal parttimers in het huishouden			✓	✓
ParkTar(i)	Parkeertarief per uur in Euro	✓	✓		
FemLic(i)	Dummy-variabele met waarde 1, als alle rijbewijzen in het huishouden in het bezit zijn van vrouwen	✓	✓		
Stud	Dummy-variabele met waarde 1, als het hoofd van het huishouden een student is	✓			
Land(i)	Dummy-variabele met waarde 1, als het huishouden in landelijk gebied woont (urbanisatiegraad = 1)	✓	✓		
G_ZSSted(i)	Dummy-variabele met waarde 1, als het huishouden in zeer sterk stedelijk gebied woont (urbanisatiegraad = 5)	✓			
Worker	Dummy-variabele met waarde 1, als er één of meer werkenden in het huishouden aanwezig zijn	✓			
Agri(i)	De fractie landbouw; Z-landbouw/Z-totaal	✓			

Dummy-variabelen hebben default de waarde 0, en de waarde 1 onder de aangegeven conditie. Met het ✓ is aangegeven dat de coëfficiënt voor het betreffende alternatief wordt meegenomen.

Q. CONCEPTUAL MODEL FOR CARSHARING SUPPLY AND DEMAND

The carsharing market is a fast-growing market and developments in the carsharing service level, among which the accessibility and the costs, are expected to have a large impact on the willingness to become a carsharing member, just as the national awareness of carsharing in general. In order to gain a better insight in the development of carsharing demand over time, a causal relationship diagram is made, see also Figure 27.

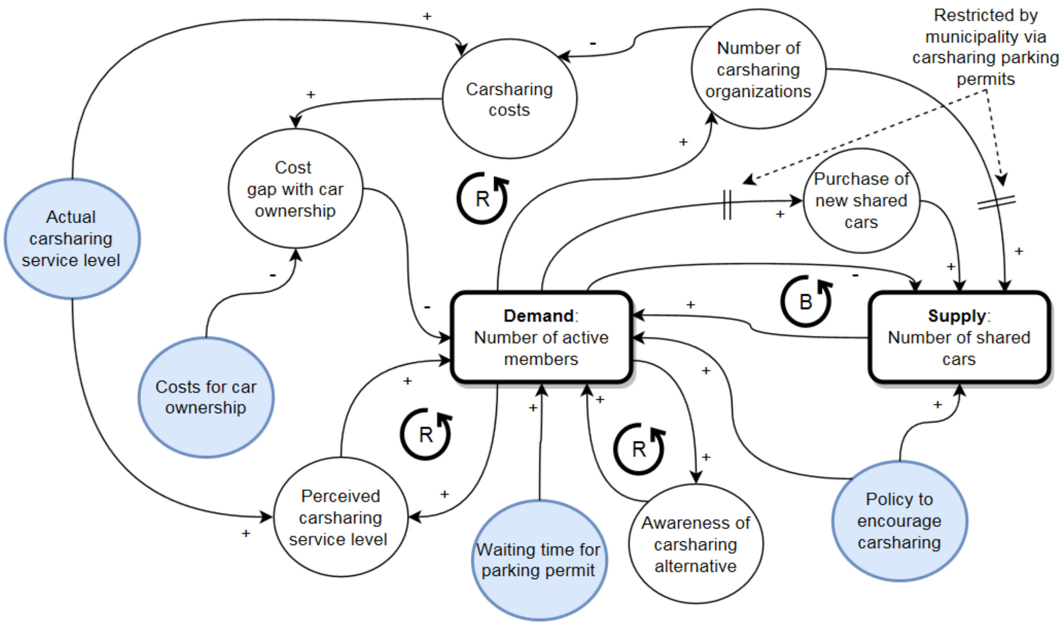


FIGURE 27: CONCEPTUAL MODEL FOR SUPPLY AND DEMAND MODEL OF CARSHARING ON AN AGGREGATED LEVEL

As can be seen, various reinforcing loops are present, visualizing the possibilities for further growth of carsharing. The growth is however not limitless. The awareness of the carsharing alternative will for example never exceed 100%. Moreover, a better awareness of the actual service level is also expected to increase the carsharing demand, but after a certain time everybody will have a correct image of carsharing. Marketing and actual improvements in the service level might still raise the perception, but at a certain moment saturation is reached. The reinforcing loop that includes the carsharing costs is also expected to reach equilibrium. Due to market mechanism carsharing usage costs are likely to reduce and might even become lower than private car usage costs, but carsharing will never be offered for a lower price than the cost price of the service. It should be noted that the reinforcing loops can also turn out to be a negative spiral: a lower awareness will result in less active members and a reduced demand can result in higher carsharing costs, which will further lower the demand.

An important limiting factor in the growing demand is the development of the supply. As long as the supply side is not restricted, the reinforcing loops will continue until saturation is reached. In the interviews Car2go and Greenwheels however both mentioned that they are not able to grow further in certain areas, because municipalities limit the number of parking permits for shared cars.