Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Car sharing preferences and mode substitution: a stated choice experiment

Andrea Papu Carrone[a]*, Valerie Maria Hoening[a], Anders Fjendbo Jensen[a], Stefan Eriksen Mabit[a], Jeppe Rich[a]

[a]*Technical University of Denmark, Bygningstorvet Bygning 116, Kongens Lyngby 2800, Denmark*

Abstract

Car sharing is an emerging mode of transport that enhances the mobility of individuals. However, it is still not clear which traditional transport modes are substituted or complemented by car sharing services. This paper aims at describing how individuals value the different features of car sharing services and analyzes the degree of substitutability with traditional transport modes including private cars, public transport and bike. The analysis is based on a stated choice experiment for the choice of transport mode and the design is pivoted with respect to observed trips in order to imitate realistic choice situations for each participant. In order to facilitate oversampling of young and educated individuals who are more likely to consider car sharing as a mode of transport the survey is distributed online primarily within a university environment. A mixed logit model that accounts for panel effect reveals several interesting findings. First, we derive the willingness to pay for vehicle reservation, parking availability and convenient access to vehicles, and show that these characteristics of car sharing systems may affect adoption. Secondly, it is show that free-floating car sharing is a strong competitor of public transport and bike trips and to a lesser extent private car trips.

Keywords: Car sharing; Mode choice; Stated choice experiment; Efficient design

1. Introduction

Car sharing services provide its members with access to a fleet of vehicles which can be rented for short time periods on an 'as-needed' basis (Shaheen et al., 1998). Several forms of car sharing exist but are typically classified into two generic types: i) station-based car sharing and ii) one-way free-floating car sharing. The former mostly

* Corresponding author.
E-mail address: avpa@dtu.dk

encompasses round trips and, as the name suggests, vehicles can only be accessed and returned at a number of fixed locations. The latter enables users to pick up and return vehicles anywhere within a predefined area of operation. These services enhance the mode choice alternatives, potentially reducing the need to own a private car and could also potentially complement public transport and non-motorized alternatives.

It has been argued that car sharing services will affect urban mobility and livability by providing a flexible yet efficient mode of transport to the market. First, it has been observed that in some cases the existence of car sharing services has led to a reduction of private car ownership (Becker et al., 2018; Firnkorn and Müller, 2012; Martin and Shaheen, 2016). Since shared vehicles will have a higher utilization degree compared to privately owned cars, less urban space for parking facilities would be required. In the long-run this may lead to changes in the way urban land is used. Furthermore, it has been reported that individuals who do not own a car and are members of car sharing services, tend to travel fewer kilometers when compared to those with private cars given their increased judiciousness in travel behavior (Cervero et al., 2007). Secondly, if car sharing is based on fleets of electric vehicles, then car sharing could contribute to a further reduction of the CO_2 emissions (Millard-Ball et al., 2005; Shaheen and Cohen, 2012). Common concerns about electric vehicles range would in general not constitute a problem since car sharing is mostly suited for urban areas and short trips. A research question which is still not clearly addressed in the literature is related to the substitutability of car sharing and if it acts as a substitute or a supporter of public transport and biking trips. Some argue that car sharing could induce members to become more intermodal by combining different transport modes such as biking and walking (Kopp et al., 2015) while others shown that specifically free-floating car sharing systems are in strong competition with public transport modes (Becker et al., 2017; Ciari et al., 2014; Firnkorn and Müller, 2012). The effects of car sharing on the demand for traditional transport modes, the total travelled mileage by vehicles and its wider effect on congestion remains an open research topic.

The socio-economic profile of car sharing members has been documented by many researchers. Essentially, they agree that users are generally male, younger than the age of 35 (Firnkorn and Müller, 2012), residing in urban areas (Prieto et al., 2017), have high education levels (Le Vine et al., 2014) and higher incomes (Kopp et al., 2015). In the first part of this paper we document the car sharing members profile and discuss if the profile of members in Denmark corresponds with the previous findings from a variety of cities in North America and Europe. While several papers have focused on the characteristics of car sharing users at the individual level, only few studies have investigated the travel choice situations at the level of the trip (Ceccato and Diana, 2019; Ciari and Axhausen, 2012). However, the use of car sharing is not only affected by the individuals' profile and preferences but by the specific situation and the characteristics that make car sharing an attractive mode of transport. Users satisfaction with respect to car sharing characteristics is often associated to safety, cost, parking difficulty and travel convenience as investigated in Efthymiou et al. (2013) in a stated choice survey. In addition, Kortum (2012) discusses that parents who travel with small children and thereby require special seating facilities do not find car sharing an appealing transport alternative. To further explore the preferences of individuals in a variety of different situations (commuting, shopping, leisure, and travelling with children) we present a trip level analysis based on a mode choice stated preference survey where respondents are framed in different contexts inspired by everyday life situations.

The contribution of the paper is three-fold. First, we analyze the profile of car sharing members (both station-based and free-floating) and compare this with other international studies. The car sharing market in Denmark was introduced in 1997 (Olsen and Retting, 2000) while the substantial growth is only recent given that different free-floating schemes started to operate from 2015. Studies that focus on the upsurge in car sharing services in Denmark are limited and have been conducted only before that free-floating car sharing started to operate (Haustein and Nielsen, 2015; Olsen and Retting, 2000). Secondly, the paper focuses in free-floating car sharing and aims at analyzing these services as a transport mode alternative. By collecting stated preference data and formulating an econometric model for the choice of mode a wider understanding of drivers and preferences with respect to these services are offered. In particular we derive the willingness-to-pay for different car sharing features such as access time, possibility of reserving vehicles in advance and the time spent while searching for parking spots and show that further than the price of the service, these 'transaction costs' also affect adoption of car sharing. As a third contribution we investigate the mode substitutability and show that the main competing mode is that of public transport. In order to ensure that choice situations are realistic for every respondent, the experimental design is pivoted with respect to an observed trip and the time and cost attributes are derived from the Danish National Transport Model (Rich and Hansen, 2016) and the Danish National Travel Survey (Christiansen, 2018). Moreover, choices are introduced in different contexts in order to measure the impact of different situations. As an example, we investigate the effect of 'uncomfortable trips' which include travelling with small children, carrying heavy shopping bags and travelling on rainy days.

The remainder of this paper is organized as follows. Section 2 reviews the car sharing membership profile in the context of Denmark. Section 3 describes the stated choice experiment design and questionnaire whereas Section 4 presents the model estimation and results. In Section 5 we discuss the findings of the model and finally in Section 6 the conclusions are offered.

2. Car sharing membership in Denmark

Since membership to a car sharing scheme does not necessarily imply the use of the system (especially for free-floating car sharing services for which membership is generally free of charge), it would be more suitable to explore the profile of car sharing users rather than of car sharing members. However, because this data is generally not available most research so far has focused on the analysis of the profile of car sharing members. We conduct the membership analysis based on the Danish National Travel Survey. The survey consists of a one-day travel diary of a representative sample of the Danish population (38,819 individuals). In Denmark, only 0.57% of the population is a member of a car sharing scheme while in the Greater Copenhagen area this share is 4.34%. Car sharing membership in Denmark is not as frequent as in neighboring countries with more developed tradition of car sharing. For example, Germany has a membership share just below 2.5% of the population (BCS, 2018) despite its higher car ownership.

Table 1 presents socio-demographic characteristics of the Danish population, of the population of the Greater Copenhagen area and of car sharing members. Male and young adults between the age of 25 and 54 years are shown to be more prone to join a car sharing scheme. Car sharing members have higher incomes than the average population in Denmark and in Copenhagen. Also, the percentage of individuals that have acquired a university degree is almost double when comparing car sharing members to the average Danish population. People who do not own a car in their household is more likely to join a car sharing services compared to those who have at least one car. These findings match the previous assessments on car sharing members' characteristics available for other countries in Europe and North America.

The limited size of the car sharing market in Denmark together with its short history, particularly with respect to free-floating car sharing, motivates this study to further explore the potential for this new market segment. From Table 1, it can be observed that the population of the Greater Copenhagen area constitutes a large share of young adults with high education and income level that live in households with zero or one car only. Given the similarity between the socio-economic profiles of car sharing members and the Greater Copenhagen population it is fair to believe that this emerging transport alternative will be well received as an alternative mean of transport in the capital region.

Table 1 Socio-demographic characteristics based on the Danish National Travel Survey.

		Denmark (Sample size= 38,819)		**Greater Copenhagen residents (Sample size= 5,113)**		**Car sharing members (Sample size= 222)**	
Variable		**N**	**%**	**N**	**%**	**N**	**%**
Gender							
	Male	19,383	49.93%	2,546	49.79%	131	59.01%
	Female	19,436	50.07%	2,567	50.21%	91	40.99%

Age							
	<18	6,103	15.72%	599	11.72%	0	0%
	18 - 24	3,188	8.21%	417	8.16%	18	8.11%
	25 - 34	4,315	11.11%	1,237	24.19%	50	22.52%
	35 - 44	5,274	13.59%	896	17.52%	50	22.52%
	45 - 54	5,893	15.18%	699	13.67%	51	22.97%
	> 55	14,046	36.18%	1,265	24.74%	53	23.87%
Annual gross income							
(1,000 DKK)	Low: < 200	23,698	61.05%	2,943	57.56%	94	42.34%
	Mid: 200 – 600	12,990	33.46%	1,817	35.54%	99	44.59%
	High: > 600	2,131	5.49%	353	6.90%	29	13.06%
Occupation							
	Student	9,565	24.64%	1,316	25.74%	24	10.81%
	Employee	18,197	46.88%	2,687	52.55%	157	70.72%
	Unemployed or retired	11,057	28.48%	1,110	21.71%	41	18.47%
Education level							
	Secondary school	15,894	40.94%	1,732	33.87%	48	21.62%
	Short university	18,594	47.90%	2,149	42.03%	102	45.95%
	Long university (Master or PhD)	4,331	11.16%	1,232	24.10%	72	32.43%
Number of cars in household							
	0	6,068	15.63%	2,235	43.71%	88	39.64%
	1	19,085	49.16%	2,403	47.00%	99	44.59%
	2 or more	13,666	35.21%	475	9.29%	35	15.77%

3. Stated choice experiment

Choice studies are preferably based on revealed preference data as it allows revealing actual observed preferences. However, considering that car sharing is not yet widely spread in Denmark and that the share of trips that use car sharing as a mode of transport is limited, it is not realistically possible to conduct a mode choice analysis based on revealed data. A common method to study emerging alternatives within transport is to elicit preferences from the respondents by presenting them with hypothetical choice experiments. Stated choice experiments offer a practical way of capturing preferences for unavailable alternatives and to collect multiple choice tasks per respondent, thus needing fewer individuals in the data collection phase. Furthermore, the stated choice design allows to tailor the level of variation in the choice task which generally improves the model estimation (Train, 2009). On the other hand, since the information is not directly observed, it is subjected to response biases.

One of the most important aspects when generating the stated choice experiment is to ensure that respondents are presented with realistic attribute values in the choice task. That is, travel time that is presented in the experiment should be similar to the travel time that each respondent faces in reality. The idea of building customized stated choice experiments based on revealed data in order to reproduce a realistic situation for respondents is not new (Louviere et al., 2000). However, most of the studies on car sharing mode choice have applied stated choice experiments solely based on hypothetical trips with no connection to the respondent experience (e.g. Catalano et al., 2008; De Luca & Di Pace, 2014). To the knowledge of the authors only two previous studies have tailored the stated choice experiment to the respondents' revealed information (Ceccato and Diana, 2019; Ciari and Axhausen, 2012).

In this study we conduct a mode choice stated preference experiment where realism is enhanced by customizing the choice tasks to each respondent. Each respondent receives multiple choice tasks and the set of 'games' thereby constitute a panel for each individual. All of the choice tasks in the experiment present public transport, bike and free-floating car sharing alternatives. In addition, if the participant owns a car he is also presented with car as an alternative mode of transport. Other studies investigating car sharing do not include bike as an alternative (Catalano et al., 2008; Ciari and Axhausen, 2012; Schmöller et al., 2015). Since this study is located in Denmark where cycling represents over 30 % of the trips in the inner Copenhagen, it is relevant to include this alternative.

3.1. Target sample and survey distribution

The survey was conducted online during April and May 2018 and the distribution methods were email, Facebook and the University portal. The survey was initially distributed within the university community –students and staff- and later a snowballing method was implemented by asking the respondents to recommend the survey to other residents in Denmark. Individuals were eligible for our study if they had a permanent residence in Denmark, owned a driving license and reported a trip that exceeded 2 kilometers.

Internet surveys are advantageous because of their flexibility to design customized choice experiments, their low cost, their ease to distribute and lower non-response rate. Nevertheless, they are generally criticized for being vulnerable to sampling error as they tend to oversample specific segment of the population - internet users - (Dillman et al., 2009). In this case, however, the aim is not to produce a representative sample but rather to oversample specific segments with a higher likelihood of using car sharing services. In order to accomplish such oversampling the survey is distributed within the university environment where the share of young individuals with high level of education and experience with technology is higher. As previous studies have already shown, this target group is more likely to consider using car sharing and by oversampling this segment we attain a desirable improved efficiency of the estimated parameters (Ben-Akiva and Lerman, 1985).

3.2. Questionnaire design

The mode choice survey was composed of four parts. The first part of the survey consisted of general information about the respondents' travel patterns, including residential location, commuting destination, car availability, car sharing membership and use. Furthermore, the respondents were asked to provide specific details about their last commuting trip, including departure and arrival location and travel time. Moreover, the respondent was presented with three hypothetical situations of non-commuting trips (grocery shopping, going to perform a sport/hobby, taking a child to school) and was asked to select the ones that were familiar to his travel patterns. This information together with the detailed description of the last commuting trip was used as a basis to design realistic choice experiments for each participant. The second and third part of the survey constituted two stated experiments. The first consisted of a mode choice exercise in the context of a commuting trip while the latter pictured a trip in a non-commuting situation that was randomly selected from the subset of situations that the respondent had previously confirmed as being realistic. Finally, socio-demographic questions were asked.

In the stated choice experiments, the respondents were asked to choose between four alternatives: public transport, car, car-sharing and bike. The private car was only presented to those who owned at least one vehicle in their household. The values of the alternatives' attributes presented in each choice task were derived as a variation of the values calculated based on the reference trip stated by the participant. Just before the stated preference experiments, respondents were informed about car sharing alternatives in general and more specifically about how free-floating car sharing systems operate. They were asked to assume that their trip was performed within a free-floating car sharing area of operation and that all of the alternatives presented were available. They were asked to assume that the differences between the alternatives relied only on those attributes included in the survey. For each choice task, every respondent had to select only one of the alternatives presented to him/her. To avoid bias due to the placement of each alternative, the positions were randomly shifted across the choice tasks.

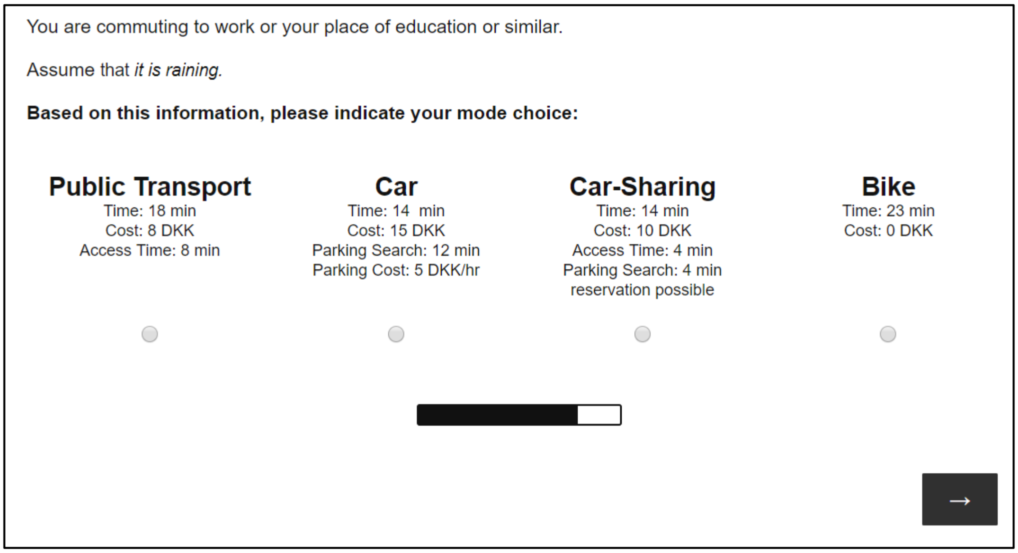

Fig. 1. Example of a choice task in the commuting trip stated choice experiment.

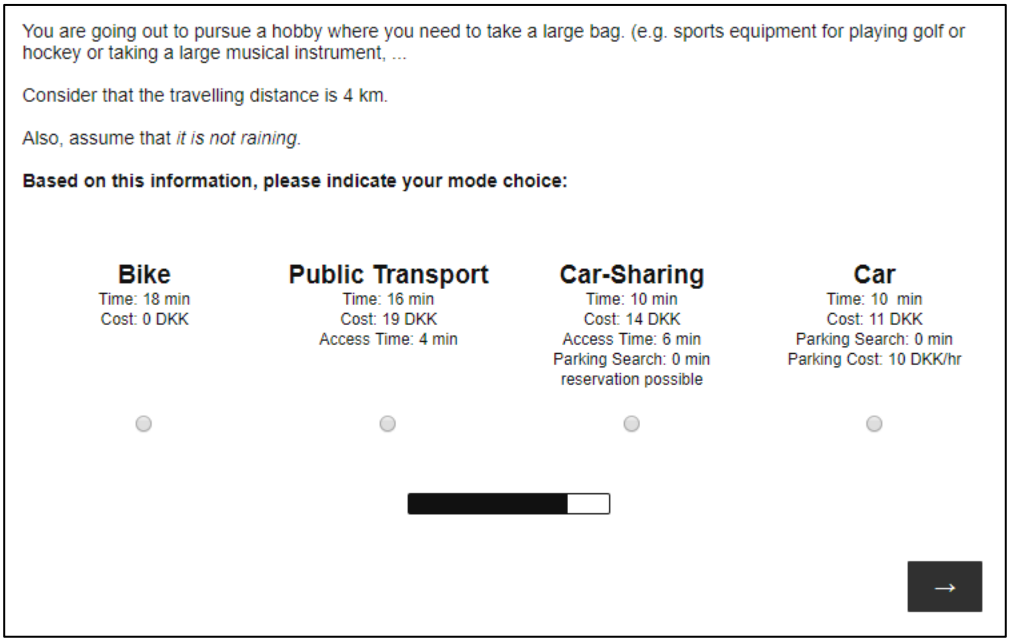

Fig. 2. Example of a choice task in the non-commuting (leisure) trip stated choice experiment.

While the first stated choice experiment in the survey corresponded to a commuting trip, the second corresponded to a non-commuting trip with a purpose of relevance to the respondent (shopping, leisure or travelling with a child). A discomfort variable associated to the carrying of large and heavy items was fitted to the non-commuting trip purposes. Thus, the following situations were included in the experiments:

- Going grocery shopping (carrying several and heavy bags of monthly purchase / carrying less than two regular bags)

- Leaving the house to pursue a sport/hobby (carrying big sport equipment e.g. golf / carrying a gym bag)

- Taking a child to daycare/school (a small child who needs a special seat in the car / a child older than 8 years)

An example of a choice task from the commuting and from the non-commuting experiment are shown in Fig. 1 and Fig. 2, respectively. The first line in the choice task describes the scenario in which the trip is performed and the following line the weather conditions (raining or not raining). Two contextual attributes that represent the weather and the discomfort of carrying items during the trip are included in the non-commuting choice tasks description while the commuting tasks only included weather in the context description. Then, a set of alternative specific attributes characterize each of the mode alternatives.

3.3. Definition of attributes

The values of the time attributes are based on the reference trip information provided by the participant in the first part of the survey. In particular, the travel time revealed by the participant is the reference value for the “observed” alternative whereas the reference values for the “non-observed” alternatives are calculated as the product of the revealed travel time and the ratio between average travel times of the different transport alternatives derived from the Danish National Transport Survey. The travel time for car and car sharing alternatives is assumed to be equal.

The reference value for the cost of public transport is calculated from the Danish National Transport Model based on the revealed trip distance. It was taken into account that the cost of public transport for a commute trip is different from a non-commuting trip. This is because commuters have a higher likelihood of using monthly cards and thereby attain a lower cost per trip. Thus, the reference value for the public transport cost attribute used in the commuting experiment is different from the one used in the non-commuting experiment. As these experiments do not consider a strategic decision, we do not include insurance or taxes for the private car alternative, since these are fixed costs that do not directly influence the use of car. On the other hand, amortization or deterioration is included to account for the attrition due to frequent car use. Therefore, the per kilometer cost for car is derived from the Danish Transport Economic Unit Price Study (Pilegaard et al., 2017) and consists of both fuel and amortization costs. To define the cost of the car sharing alternative we assume that individuals who use free-floating car sharing to commute would have a monthly subscription with a discounted price, hence two different prices are defined for car sharing commuting trips and non-commuting trips. The possibility to have two different prices is consistent with the different plans which are offered by the local suppliers of free-floating car sharing in Copenhagen. It is free to become a member while the minute of use is assumed to be 1.5 DKK/min for commuting trips and 3 DKK/min for non-commuting trips.

The attribute access time is included in the public transport as well as in the car sharing alternative. Based on previous stated preference studies (Catalano et al., 2008; Ciari and Axhausen, 2012; Schmöller et al., 2015) and the known distribution of the variable access time for public transport in Copenhagen, the attribute levels are defined to vary between 2 and 8 minutes. Parking costs are based on parking prices in Copenhagen (Visit Copenhagen), which range from 5 DKK/h to 21 DKK/h. Parking cost for car sharing is zero since it is covered by the service provider. Parking search, which represents the time that is spent searching for an available parking space, is included for both car and car sharing alternatives and ranging from 0 to 12 minutes. Values of a similar range have been used in in previous studies (Catalano et al., 2008). For the car sharing alternative, a binary attribute which indicates whether it is possible to reserve the vehicle prior to the trip is also included.

The attributes rain and discomfort describe the context in which the trip is performed and are included in the experiments as binary attributes.

The values of the attributes of each alternative in the choice tasks are defined as relative variation with respect to the reference attribute level. The magnitude of these variations has a given range, which depends on specific assumptions of how some of the alternative attributes could vary in the future. In this case, we include scenarios where the car sharing cost is exceptionally cheap in order to observe whether respondents would be more prone to choosing this new mode in such cases. Furthermore, some attribute levels are not defined equidistant since realism of the values presented in the choice tasks was prioritized. In order to allow for estimation of non-linear effects for all time and cost attributes more than two levels are required. Hence, while contextual attributes and the alternative specific dummy for reservation of car sharing have only two levels, i.e. 0 and 1; all time and cost attributes involve four levels. The following Table 2 shows the defined attributes, the reference value and the attribute levels used to create the specific experimental design. The attributes that indicate * in the Reference column are specifically calculated for each respondent pivoting the percentage of increase or decrease in time and cost.

Table 2. Attributes and attribute levels used to generate the experimental design.

Alternative	Attribute	Unit	Reference	Attribute levels			
Bike	Travel time	[min]	*	-20%	-10%	0	+10%
Car	Travel time	[min]	*	-30%	-10%	+10%	+30%
	Cost	[DKK]	*	-25%	0	+25%	+50%
	Parking Cost	[DKK/h]	5	-100%	0	+100%	+150%
	Parking Search	[min]	4	-100%	0	+100%	+150%
Car sharing	Travel time	[min]	*	-30%	-10%	+10%	30%
	Cost	[DKK]	*	-50%	-25%	0	+25%
	Access Time	[min]	4	-50%	0	+50%	+100%
	Parking Search	[min]	4	-100%	0	+100%	+150%
	Reservation				yes	no	
Public Transport	Travel time	[min]	*	-20%	-10%	0	+10%
	Cost	[DKK]	*	-50%	-25%	0	+25%
	Access Time	[min]	4	-50%	0	+50%	+100%
Contextual attributes	Rain				yes	no	
	Discomfort				yes	no	

3.4. Efficient design

The design of the experiments - how the attribute values are combined for the alternatives in each choice task- is generated with the software Ngene (ChoiceMetrics, 2018) using the RSC (Relabeling, Swapping and Cycling) algorithm. An efficient design which is capable of handling attributes interdependencies[†], including contextual attributes[‡] and generating a pivot design using a reference trip for each individual is determined.

† The travel time for car and car sharing presented in each choice task are equal.
‡ Two context specific attributes that do not vary for each alternative are included in each choice task: rain and discomfort.

In order to build a customized efficient pivot design the reference trip characteristics of each individual would theoretically be required before hand. This would require a 2-step data collection, first to collect the trip characteristics and later -after the efficient design is generated- to complete the choice experiment. Different strategies have been explored to avoid the 2-step data collection which is generally inconvenient (Rose et al., 2008). We use the presumably simplest strategy and generate a pivot efficient design base on population averages. More specifically, we generate D-efficient experimental designs with uninformative priors which consist of 8 blocks with 3 choice tasks each. Ultimately, each individual receives 6 tasks, 3 corresponding to a commuting trip and the remaining 3 corresponding to non-commuting trips.

4. Stated choice model estimation

4.1. Sample characteristics and estimation dataset

After data cleaning, the final sample size of the stated choice experiment is 179 participants which leads to a total of 1005 observations. An overview of the socio-demographic variables (Table 3) allows for a qualitative picture of the sample profile. The key demographic results include a balanced gender split, but, as it was expected given the distribution of the survey on Internet and primarily within the university environment, the age distribution is highly skewed towards young people between the age of 18 and 34 years. This also explains the high share of participants with low income, no car availability in the household and no children. Furthermore, given the target of our sample we observe a large majority of the sample with a long education profile.

Table 3. Sample characteristics. Sample size = 179 individuals and 1005 observations.

Variable		**N**	**%**
Gender	Male	97	54.2%
	Female	82	45.8%
Age	18 – 24	47	26.3%
	25 – 34	88	49.2%
	35 – 44	24	13.4%
	45 – 54	13	7.3%
	> 55	7	3.9%
Annual gross income	Low: < 200	90	50.3%
(1,000 DKK)	Mid: 200 – 600	48	26.8%
	High: > 600	41	22.9%
Education level	Secondary school	12	6.7%
	Short university	54	30.2%
	Long university (Master or PhD)	113	63.1%
Occupation	Student	92	51.4%
	Employee	79	44.1%
	Unemployed or retired	8	4.5%
Household type	Single	52	29.1%
	Multiple with no children	76	42.5%
	Multiple with children	51	28.5%
Cars in household	0	114	63.7%
	1	47	26.3%
	2 or more	18	10.1%

Public transport monthly card	Yes	48	26.8%
	No	131	73.2%
Bike ownership	Yes	171	95.5%
	No	8	4.5%
Car sharing member	Yes	52	29.1%
	No	127	70.9%
Car sharing use	Never	137	76.5%
	Rarely	23	12.8%
	Every month	12	6.7%
	Every week	7	3.9%

Table 4 tabulates mode responses across all our choice experiment questions. There is overall a tendency towards choosing bike and public transport alternatives. Additionally, there are noticeable differences in the tendency to choose car alternatives (private car and car sharing) when comparing commuting and non-commuting experiments. Both car alternatives are more popular for the non-commuting trips than for commuting trips.

Table 4. Distribution of choices among alternatives.

	Car sharing	**Public transport**	**Private car**	**Bike**
Average	10.9 %	29.6 %	14.4 %	45.2 %
Commuting experiment	8.6 %	30.9 %	9.7 %	50.8 %
Non-commuting experiment	13.2 %	28.3 %	19.0 %	39.5 %

In order to provide information with respect to the typical choice tasks, Table 5 illustrates the distribution of the mode specific attributes presented in each of the stated choice experiments. The travel time of the commuting trips tended to be longer and therefore also more costly. On the other hand, the presented travel cost for public transport and for car sharing of commuting trips is lower given the assumption of prices as previously stated.

Table 5. Distribution of the attributes presented for each alternative mode in the commuting and non-commuting experiments.

		Commuting experiments					**Non-commuting experiments**				
Alternative	**Attributes**	**N**	**Mean**	**Std Dev**	**Min**	**Max**	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Private car	Travel time [min]	195	21.6	13.7	4	91	195	14.1	6.9	3	29
	Travel cost [DKK]	195	18.1	11.4	3	78	195	11.7	5.8	2	24
	Parking search time [min]	195	7.8	4.1	0	12	195	8.1	4.2	0	12
	Parking cost [DKK]	195	7.6	5.7	0	15	195	7.7	5.6	0	15
Bike	Travel time [min]	537	35.2	20.7	4	136	537	25.4	12	7	48
Public transport	Travel time [min]	537	32	19	4	136	537	23.2	11	6	44
	Travel cost [DKK]	537	10.6	4.3	4	25	537	15.3	5.8	6	28
	Access time [min]	537	5	2.2	2	8	537	5	2.2	2	8
Car sharing	Travel time [min]	537	19.2	12.4	2	91	537	13.4	6.9	3	29
	Travel cost [DKK]	537	24.8	16.6	2	131	537	35.8	20.3	6	82
	Parking search time [min]	537	5.5	4.4	0	12	537	5.5	4.5	0	12
	Access time [min]	537	5	2.2	2	8	537	5	2.2	2	8
	Reservation dummy	537	0.5	0.5	0	1	537	0.5	0.5	0	1

4.2. Model estimation

A mixed logit model that allows accounting for panel correlation among choices from the same respondent in the stated choice dataset is estimated using the software Biogeme (Bierlaire, 2003). The utility specification is defined as:

$$U_{jnt} = ASC_j + \boldsymbol{\beta}_j^{\boldsymbol{X}} \boldsymbol{X}_{jnt} + \boldsymbol{\beta}_j^{\boldsymbol{T}} \boldsymbol{T}_{nt} + \boldsymbol{\beta}_j^{\boldsymbol{S}} \boldsymbol{S}_n + \mu_{jn} + \varepsilon_{jnt}$$

Where U_{jnt} is the utility that each respondent n associates to alternative j, in the choice task t. $\boldsymbol{X}_{jnt}$ is the vector of all the attributes associated to each of the alternatives in the choice task t; $\boldsymbol{T}_{nt}$ is the vector of contextual attributes in the choice task t; and $\boldsymbol{S}_n$ is the vector of background characteristics of individual n. μ_{jn} is a normally distributed error-term (with mean zero and standard deviation σ_μ) across individuals. Finally, ε_{jnt} are identical and independently distributed extreme value type 1 error terms.

The estimation process first assumed a simple reference model formulated as a multinomial logit model. The utility specifications were gradually extended by including additional explanatory variables one by one to better understand their impact with respect to model fit. Socio-demographic variables were added in the model as generic and alternative specific variables, and later the models were tested to retain the best performing specification. As a guideline, variables were kept when they showed to be statistically significant.

4.3. Model results

We tested various specifications for the model, with the final model presented in Table 6. All parameters that are significant at a 10% level are included in the results table where different significance levels are recognized. All the significant coefficients have the expected sign. In particular, travel time and cost are negative, an increase in any of these attributes is thereby considered less attractive for the respective mode. The added cost of parking for the car alternative is found to be insignificant.

An alternative specific coefficient for access time is estimated in the public transport and car sharing alternatives. While the estimate for public transport is insignificant, the coefficient estimate for the car sharing alternative is significant and negative. It is observed that for the car sharing alternative, the estimated access time parameter is almost twice the value estimated for the coefficient of travel time. This indicating that individuals are more reluctant to spend their time walking to access the car compared to time spend travelling with the car. The effect of the attribute for the time spent on searching for an available parking space is significant and negative as it was expected. We test a generic parameter for car travel time and time spent during parking search and observe that these two estimates are significantly different. This indicates that individuals have a different perception of time inside the vehicle during the trip and time during parking search. A dummy variable that accounts for the possibility to reserve a vehicle in the car sharing system in order to guarantee the availability is shown to have a significant positive effect on choosing car sharing as a transport mode.

The model is estimated jointly for commuting and non-commuting scenarios, a dummy variable for non-commuting trips reflects the purpose effect of non-commuting trips with respect to commuting which was chosen as the reference category. The results show that individuals are less likely to choose bike as a mode of transport for non-commuting trips compared to commuting trips. In contrast, if available, individuals are more likely to choose their private car for non-commuting trips than for commuting. This could possibly be related to the fact that leisure and shopping trips (non-commuting) are more often carried out in larger group and other transport alternatives than bike are thus more convenient. However, it also reflects a case specific finding for the city of Copenhagen where cycling is considered an important commuting transport mode and not only a leisure transport alternative.

The dummy variable for rain is shown to have a significant negative effect on the choice for bike, whereas the effect of rainy days compared to days with no rain has no significant effect when choosing public transport, car sharing and car.

Furthermore, a dummy variable that describes situations of travelling discomfort is included when relevant for the design. That is, if the context involves carrying a large number of bags, heavy equipment or stroller and seat facilities for smaller children. The discomfort dummy variable shows a statistically significant negative effect for bike and public transport alternatives. It appears that bike and public transport are perceived as more uncomfortable modes when travelling with large and heavy items compared to car sharing and car (if available) alternatives. Surprisingly, for those who own a car, the likelihood of choosing to use their own car or a car sharing is indifferent.

The model was enhanced further by including a set of individual specific characteristics. A variable for the number of cars in the household is included in the utility specification of the car alternative. Since the car alternative availability is conditioned on owning at least one car in the household, it is not possible to capture the effect of an owned car. Instead, we include the logarithmic transformation of the number of cars to reflect the diminishing effect of the numbers of cars owned per household on the likelihood to select the car alternative. A dummy variable for bike ownership and for public transport monthly card holder are included in the utility specifications, respectively. As expected, the effect of the three variables is positive and significant. For the car sharing alternative a dummy variable for whether the respondent was a car sharing member was tested and found to be insignificant. However, a dummy variable for frequent car sharing users (more than once per week) proved to have a positive effect on the likelihood of choosing car sharing as an alternative.

In the same way as suggested in previous studies (Firnkorn and Müller, 2012), we find that males are more likely to select car sharing compared to females. Age and income were initially included in the model and tested with different functional forms but were not found to contribute significantly. This could be interpreted as if there is no significant difference in the preferences towards choosing car sharing within age and income groups but most likely it reflects limited variation in the sampled targeted group. The coefficient for employed individuals which enters the utility specification of public transport and bike is negative compared to the reference level of unemployed (mainly students) individuals. This suggests that, employed individuals are more reluctant to use public transport and bike than to use car sharing or car (if available) compared to unemployed individuals. The effect of the household composition is included in the model with two dummy variables: single and children. The effect of single households showed not to be significant while the effect of children in the household gave a highly significant effect. Individuals who live in households with children are more likely to select bike or car (if available) than public transport or car sharing compared to the reference group formed by those with no children. Finally, the standard deviation coefficients that account for panel effects are significant, as expected.

In order to further validate the model, the value of time (VOT) is derived from the utility specification with an average value of 59 DKK/h. This figure is lower than the Danish average VOT which is 85 DKK/h (Pilegaard et al., 2017) as confirmed more recently in Rich and Vandet (2019). Since the target population of the survey is highly composed by students, the average income of our sample is significantly lower than for the Danish population (Table 1; Table 3). Therefore, given the socio-economic characteristics of our target population it is expected that the derived VOT would be lower than the average of the Danish population.

Table 6. Model estimates of the stated choice experiment.

Variable	Car sharing	Public transport	Private car	Bike
Alternative specific constant (ASC)		0.835**	-1.49**	3.65***
		(-2.06)	(-2.04)	(4.47)
Standard deviation for panel effect (σ) [a]		0.766	2.26***	1.45**
		(1.18)	(2.90)	(2.14)
Travel time [10 min]	-0.592***	-0.592***	-0.592***	-1.47***
	(-4.24)	(-4.24)	(-4.24)	(-8.79)
Travel cost [10 DKK]	-0.607***	-0.607***	-0.607***	
	(-6.88)	(-6.88)	(-6.88)	
Access time [10 min]	-0.789*			
	(-1.64)			
Parking search time [10 min]	-0.734***			
	(-3.05)			
Reservation [dummy]	0.69***			
	(3.04)			
Non-commuting [dummy]			1.42***	-0.673***
			(3.14)	(-2.61)
Rain [dummy]				-1.98***
				(-7.89)
Discomfort [dummy]		-1.18***		-2.92***
		(-4.41)		(-8.54)
Number of cars (logarithmic)			3.47***	
			(3.05)	
Public transport monthly card [dummy]		1.43***		
		(4.78)		
Bike ownership [dummy]				1.84***
				(2.81)
Car sharing frequent user [dummy]	1.17*			
	(1.64)			
Male [dummy]		-0.571**	-0.571**	-0.571**
		(-2.16)	(-2.16)	(-2.16)
Employed [dummy]		-0.923***		-0.923***
		(-3.17)		(-3.17)
Household with children [dummy]			1.3***	1.3***
			(3.39)	(3.39)
Number of observations				1,074
Number of individuals				179
Number of draws				1,000
Number of estimated parameters				24
Log likelihood				-820
Null Log likelihood				-1067
rho-square-bar				0.207

[a] t-test against 1

*, **, ***: significance at 10%, 5% and 1% respectively.

5. Results and discussion

5.1. Preferences towards car sharing as a mode

From the results of the model presented in Table 6 a number of findings with respect to choosing free-floating car sharing as a mode of transport can be revealed:

- The value of time for the access time with respect the car sharing vehicle is 78 DKK/h while the value of time for travel time is 59 DKK/h. It confirms that convenient access to car sharing vehicles is a very important feature as individuals value the access time more than 30% higher than the actual travel time inside the vehicle.
- The value of time spent searching for an available parking space with a car sharing vehicle is 20% higher than the value of time of the actual travel time. This raises the importance of parking availability for these services in order to motivate their use.
- On average individuals are willing to pay an additional 11 DKK in order to guarantee a reservation of the car sharing. Assuming the hour prices for car sharing services presented in this stated experiment, this fixed quota is equivalent to using a vehicle for 4 to 8 minutes of extra time.
- On a rainy day individuals perceive car sharing equally convenient as public transport and as their own car (if they have one available), although more convenient than bike.
- There is no statistical difference in the likelihood of choosing a private owned car compared to choosing a car sharing vehicle when performing a trip that requires carrying heavy or large equipment or seat facilities for children. Further research would be required to generalize our finding to the Danish population as our results could be affected by the small survey and the skewed targeted sample.
- Employed individuals are more likely to choose a car sharing vehicle than students. A similar experiment in a major university in the U.S. has found the opposite result (Zheng et al., 2009). However, the costs of private vehicle ownership as well as the cost of driving is radically different in the in the U.S. when compared to Denmark.

5.2. Mode substitution patterns

A common assumption is that car sharing is a substitute for private cars, which would lead to less traffic within urban areas (Millard-Ball et al., 2005). However, recent studies have showed that specifically free-floating car sharing systems are in fact competitors for public transport (Becker et al., 2017; Firnkorn and Müller, 2012).

To investigate this further, we simulate elasticities for travel cost and travel time from the mixed logit model as presented in Table 7. The elasticities for each alternative are presented in columns, i.e. the elasticities for an increase of 10% in the cost of car are reported in the first column of the table. The stated choice elasticities are defined by the sample and observed market shares and caution should be taken using these elasticities in a wider context.

Table 7. Elasticities of the stated choice model.

	Cost elasticities			Time elasticities			
	Car	Public transport	Car sharing	Car	Public transport	Bike	Car sharing
Car	-0.222	0.056	0.075	-0.256	0.145	0.500	0.045
Public transport	0.042	-0.340	0.219	0.048	-0.730	1.115	0.136
Bike	0.032	0.117	0.102	0.039	0.249	-1.111	0.063
Car sharing	0.061	0.280	-1.060	0.063	0.573	1.178	-0.656

Individuals are shown to be sensitive to a change in the car sharing cost. The sensitivity for the cost of the service is much larger for car sharing than for the rest of the modes. This is not surprising as i) the relative market share is lower and ii) the average user cost is higher on average. It should also be noted that from an operator point of view it is often beneficial to design a system where the price elasticity is relative large. In fact, it can be shown that if the variable operation cost approaches zero then the optimal price elasticity should approach 1. As the shared vehicles in this study are electric the variable cost is expected to be low and a price-elasticity not very different from 1 is to be expected.

From our results, it is also observed that car sharing is mainly a substitution for public transport. If for car sharing the price is decreased, the demand for car sharing increases while the demand for the other alternative modes decreases. However, due to the mixed logit model which relaxes the IIA property not all alternative modes would be affected in the same way. A decrease of 10% for the car sharing price would imply a decrease in the probability of choosing public transport of 2.2%, of choosing bike of 1% and 0.75% of choosing car. Thus, supporting the later findings of the literature that show that free-floating car sharing is a substitute for some public transport trips (Becker et al., 2017; Firnkorn and Müller, 2012). Interestingly, if car costs increase by 10% the main substitute is car sharing for which a greater increase (increase of 0.6%) than the other alternative modes are observed. The elasticities show that for the car sharing alternative the sensitivity with respect to cost is higher when compared to that of time.

6. Conclusions

This study is the first to explore the characteristics of the car sharing members in Denmark since the introduction of free-floating systems and the upsurge of this transport alternative. While confirming several findings from the literature with respect to the socio-economic characteristics of the members, our study goes on to analyze several interesting aspects of free-floating car sharing trips in Copenhagen. It is found that this service is mainly a substitute of public transport and bike trips. The importance of 'transaction costs' is also highlighted in that access time and parking search time is considered more painful than driving time. Specifically, it is found that one minute of saved access time (for car sharing vehicles) is valued 30% higher than the actual travel time, while one minute of saved searching time for an available parking place is valued 20% higher. Furthermore, individuals are willing to pay 4 to 8 minutes extra in order to reserve a vehicle. We show that guaranteed availability of car sharing vehicles, convenient access and the availability to parking are very valuable features for the users.

References

BCS, 2018. Aktuelle Zahlen und Daten zum CarSharing in Deutschland [WWW Document]. URL https://carsharing.de/alles-ueber-carsharing/carsharing-zahlen/aktuelle-zahlen-daten-zum-carsharing-deutschland (accessed 8.1.18).

Becker, H., Ciari, F., Axhausen, K.W., 2018. Measuring the car ownership impact of free-floating car-sharing – A case study in Basel, Switzerland. Transp. Res. Part D Transp. Environ. 65, 51–62. https://doi.org/10.1016/j.trd.2018.08.003

Becker, H., Ciari, F., Axhausen, K.W., 2017. Comparing car-sharing schemes in Switzerland: User groups and usage patterns. Transp. Res. Part A Policy Pract. 97, 17–29. https://doi.org/10.1016/j.tra.2017.01.004

Ben-Akiva, M., Lerman, S.R., 1985. Discrete Choice Analysis. MIT press, Cambridge, Massachusetts.

Bierlaire, M., 2003. Biogeme: A free package for the estimation of discrete choice models. Swiss Transp. Res. Conf. 1–27. https://doi.org/10.1017/CBO9781107415324.004

Catalano, M., Lo Casto, B., Migliore, M., 2008. Car sharing demand estimation and urban transport demand modelling using stated preference techniques. Eur. Transp. \ Trasp. Eur. 40, 33–50.

Ceccato, R., Diana, M., 2019. Substitution and complementarity patterns between traditional transport means and car sharing: a person and trip level analysis. Transportation (Amst). https://doi.org/10.1007/s11116-018-9901-8

Cervero, R., Golub, A., Nee, B., 2007. City CarShare: Longer-Term Travel Demand and Car Ownership Impacts. Transp. Res. Rec. J. Transp. Res. Board 1992, 70–80. https://doi.org/10.3141/1992-09

ChoiceMetrics, 2018. User manual and reference guide Ngene.

Christiansen, H., 2018. Beregning af usikkerhed og varians for Transportvaneundersøgelsen. Proc. from Annu. Transp. Conf. Aalborg Univ. https://doi.org/10.11581/dtu:00000034

Ciari, F., Axhausen, K.W., 2012. Choosing carpooling or carsharing as a mode: Swiss stated choice experiments, in: Transportation Research Board Annual Meeting.

Ciari, F., Bock, B., Balmer, M., 2014. Modeling Station-Based and Free-Floating Carsharing Demand. Transp. Res. Rec. J. Transp. Res. Board No. 2416, 37–47.

De Luca, S., Di Pace, R., 2014. Modelling the propensity in adhering to a carsharing system: A behavioral approach. Transp. Res. Procedia 3, 866–875. https://doi.org/10.1016/j.trpro.2014.10.065

Dillman, D.A., Smyth, J.D., Christian, M., 2009. Internet, Mail and Mixed-Mode Surveys: The Tailored Design Method Don. John Wiley and Sons, New Jersey.

Efthymiou, D., Antoniou, C., Waddell, P., 2013. Factors affecting the adoption of vehicle sharing systems by young drivers. Transp. Policy 29, 64–73. https://doi.org/10.1016/j.tranpol.2013.04.009

Firnkorn, J., Müller, M., 2012. Selling Mobility instead of Cars: New Business Strategies of Automakers and the Impact on Private Vehicle Holding. Bus. Strateg. Environ. 21, 264–280. https://doi.org/10.1002/bse.738

Haustein, S., Nielsen, T.A.S., 2015. Deleøkonomi i transport: udvikling, trends og potentiale. Tech. Univ. Denmark, Transp. DTU Transp. Notat 19.

Kopp, J., Gerike, R., Axhausen, K.W., 2015. Do sharing people behave differently? An empirical evaluation of the distinctive mobility patterns of free-floating car-sharing members. Transportation (Amst). 42, 449–469. https://doi.org/10.1007/s11116-015-9606-1

Kortum, K., 2012. Free-Floating Carsharing Systems: Innovations in Membership Prediction, Mode Share, and Vehicle Allocation Optimization Methodologies. Ph.D. thesis, Univ. Texas Austin, May 2012.

Le Vine, S., Lee-Gosselin, M., Sivakumar, A., Polak, J., 2014. A new approach to predict the market and impacts of round-trip and point-to-point carsharing systems: Case study of London. Transp. Res. Part D Transp. Environ. 32, 218–229. https://doi.org/10.1016/j.trd.2014.07.005

Louviere, J., Hensher, D., Swait, J., 2000. Stated choice methods: analysis and application, Cambridge University Press. https://doi.org/10.1016/S0304-4076(98)00061-X

Martin, E., Shaheen, S., 2016. Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities, Working Paper.

Millard-Ball, A., Murray, G., Schure, J. Ter, Fox, C., Burkhardt, J., 2005. Car-Sharing: Where and How It Succeeds. Washington, DC.

Olsen, M., Retting, M., 2000. Evaluering af carsharing i Danmark, Center for Mobilitet og Miljø.

Pilegaard, N., Fosgerau, M., Jensen, M.P., Lyk-Jensen, S., 2017. TERESA (Transport- og Energiministeriets Regnearksmodel til Samfundsøkonomisk Analyse) for transportprojekter, Notat 3 2006. [WWW Document]. URL http://www.modelcenter.transport.dtu.dk/-/media/Centre/Modelcenter/modeller og publikationer/TERESA-dokumentation-2006.ashx

Prieto, M., Baltas, G., Stan, V., 2017. Car sharing adoption intention in urban areas: What are the key sociodemographic drivers? Transp. Res. Part A Policy Pract. 101, 218–227. https://doi.org/10.1016/j.tra.2017.05.012

Rich, J., Hansen, C.O., 2016. The Danish national passenger model – Model specification and results. Eur. J. Transp. Infrastruct. Res. 16, 573–599.

Rich, J., Vandet, C.A., 2019. Is the value of travel time savings increasing? Analysis throughout a financial crisis. Transp. Res. Part A.

Rose, J.M., Bliemer, M.C.J., Hensher, D.A., Collins, A.T., 2008. Designing efficient stated choice experiments in the presence of reference alternatives. Transp. Res. Part B Methodol. 42, 395–406. https://doi.org/10.1016/j.trb.2007.09.002

Schmöller, S., Weikl, S., Müller, J., Bogenberger, K., 2015. Empirical analysis of free-floating carsharing usage: The munich and berlin case. Transp. Res. Part C Emerg. Technol. 56, 34–51. https://doi.org/10.1016/j.trc.2015.03.008

Shaheen, S., Sperling, D., Wagner, C., 1998. Carsharing in Europe and North America: Past, Present, and Future. Transp. Q. 52, 35–52.

Shaheen, S.A., Cohen, A.P., 2012. Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends. Int. J. Sustain. Transp. 7, 5–34. https://doi.org/10.1080/15568318.2012.660103

Train, K., 2009. Properties of Discrete Choice Models. https://doi.org/10.1017/CBO9780511805271

Visit Copenhagen, 2018. Visit Copenhagen [WWW Document]. URL https://www.visitcopenhagen.com/copenhagen/transportation/parking-zones-prices (accessed 8.1.18).

Zheng, J., Scott, M., Rodriguez, M., Sierzchula, W., Platz, D., Guo, J., Adams, T., 2009. Carsharing in a University Community. Transp. Res. Rec. J. Transp. Res. Board 2110, 18–26. https://doi.org/10.3141/2110-03