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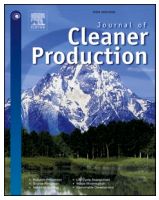

Car sharing user groups and their changes in car ownership: A latent cluster analysis

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ABSTRACT

Car sharing contributes to reducing emissions, resource depletion, and land take, by promoting more efficient use of vehicles that on average sit idle 96% of the time. But consumer adoption remains limited. User segmentation studies can inform efforts to mobilize potential users to join car sharing, and to anticipate what their needs and usage characteristics will be. This paper proposes a comprehensive segmentation method based on socio-demographic variables, which reveals differences in preferences for car sharing platform type, usage characteristics and societal outcomes of car sharing use. To do so, we apply a three step Latent Cluster Analysis to a nationwide sample of active car sharing users. This method results in a set of user segments that reflect distinct life phases, with different needs in terms of the frequency and type of trips made by car sharing. This is reflected in different preferences for car sharing platform types, as the likelihood to use peer-to-peer car sharing as opposed to business-to-consumer car sharing differs by user segment. The segments do not differ substantially in their motivations for engaging with car sharing. Yet, environmental motivations for car sharing outrank financial motivations, while social motivations play no substantial role. The clusters do show substantial differences in the changes in car ownership that occur while being an active car sharing member as well as the likelihood to use car sharing in place of a private car rather than public transport or walking and biking. We conclude that a comprehensive segmentation method based on socio-demographic variables provides actionable insights for upscaling car sharing adoption, as well as targeting specific user segments in order to optimize societal outcomes from car sharing use.

1. Introduction

Car sharing, defined as the short-term usage of a vehicle fleet available to members of a sharing organization (Shaheen et al., 2015), has received substantial attention in the literature for its potential contributions to sustainable mobility. Privately owned cars sit idle on average 96% of the time (Zijlstra et al., 2022). Car sharing makes it possible to use these existing vehicles more efficiently, in the case of peer-to-peer (P2P) car sharing (Shaheen et al. (2018), or to switch away from private car ownership altogether and replace it with a fleet of dedicated shared cars, as in business-to-consumer (B2C) car sharing. In this way, car sharing can contribute to reducing emissions and resource use by decreasing car ownership and use (Nijland and van Meerkerk, 2017), while at the same time offering households a way to cut spending on car ownership (Martin et al., 2010). Car sharing can also provide a new mobility option to households unable to afford a car (Brown, 2017), hence increasing their accessibility and promoting equity at the cost of an increase in car use. Depending on the user segments served by car sharing, the environmental benefits of car sharing can be dampened by induced car use or even turn into a net increase in emissions and resource use (Jung and Koo, 2018; Amatuni et al., 2020, Vélez, 2023).

Despite recent growth, car sharing still remains a niche (Meelen and Münzel, 2023). To facilitate further growth, it is important to understand the factors that play a role in consumer adoption of car sharing. Previous literature has shown that the decision to adopt car sharing depends on a host of factors, from socio-demographic factors such as household composition (Efthymiou et al., 2013; Meelen et al., 2019; Burghard and Dütschke, 2019) to psychosocial variables such as travel attitudes (Burghard and Dütschke, 2019) and perceived social norms (Mattia et al., 2019; Schaefers, 2013; Ramos and Bergstad, 2021). These

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factors are likely to be interrelated in complex ways, influencing levels of car sharing and effects on mobility choices. A few studies have attempted to capture these complex relations by constructing user segmentations based on the characteristics of car sharing users and attributes of their use (Reiffer et al., 2019; Julsrud and Farstad, 2020) or on the (expected) effects car sharing has on their car ownership and use (Liao et al., 2020).

In contrast to these previous segmentation studies, this study explores the idea that car sharing and its role in satisfying certain mobility needs depends to a large extent on a person's life phase (Clark et al., 2015), as characterized by a combination of socio-demographic characteristics such as a person's age, household composition, income, etc. (Prieto et al., 2017). Hence, instead of segmenting on behavioral or attitudinal variables, we cluster on socio-demographic characteristics of car sharing users. To assess what such a segmentation reveals about car sharing users, we explore the relationships between the revealed segments and their car sharing use, the motivations for car sharing and the (self-reported) changes in car ownership (before and after a person engaged in car sharing) and mode choice. Hence, the objective of this paper is to develop a segmentation method for car sharing users based on readily available socio-demographic variables, and to use it to explore policy-relevant differences between user groups.

To perform the clustering, this study applies Latent Class Analysis (LCA) on a nationwide survey of active users of car sharing, in order to discover user segments based on socio-demographic characteristics. With the three-step method (Vermunt, 2010) we then show how the resulting clusters are associated with motivations for car sharing, choice of car sharing business model (distinguishing business to consumer (B2C) and peer-to-peer (P2P) car sharing), duration and intention to continue platform membership, as well as characteristics of car sharing usage (frequency and trip types). Finally, we explore to what extent user segments differ in the effects of car sharing on mobility choices, distinguishing (self-reported) changes in mode choice and changes in car ownership (before and after one engaged in car sharing). By relating a wide range of facets of car sharing in a single model, we add to the literature by offering a distinct, yet comprehensive approach to segmenting car sharing users. For practitioners we provide valuable insights for identifying user groups based on readily available socio-demographic variables, as well as for anticipating the heterogeneous societal effects of car sharing for these groups.

The remainder of this paper is structured as follows. Section 2 presents the literature on the consumer adoption of car sharing, focusing on techniques for identifying policy relevant segments of car sharing users. This is followed in section 3 by a discussion of the data and methodology employed in this study. Section 4 presents the results of the analysis, introducing the user segments identified as well as their characteristics and the effects car sharing has on their mode use and car ownership. A discussion of the findings and their relation to the literature is provided in section 5, and the paper concludes in section 6 with a summary of the results, their policy implications, as well as limitations of this study and suggestions for further research.

2. Literature review and conceptualization

In this section we discuss the user segmentation methods that have been applied to car sharing users, and the potential societal effects of car sharing. We then conceptualize a segmentation method that aims to capture life phases. Consumer adoption studies show that car sharing users are predominantly young, highly educated males (e.g. Becker et al., 2017, Aguilera-García et al., 2022), living in high density urban areas (e.g. Priya Uteng et al., 2019). However, Kim et al. (2019) find, based on a repeated survey study, that later adopters are more varied in, among others, gender, age, income and trip motives than early adopters. For several variables the relationship with adoption remains unclear. Efthymiou et al. (2013) found that households without children are overrepresented among car sharing users because they are more flexible and would accept some level of uncertainty in terms of car availability and walking distance to a shared car. In contrast, Burghard and Dütschke (2019), Bösehans et al. (2023) and Kawgan-Kagan (2020) identify young couples who are starting to have children as car sharing target groups. Looking at income, Efthymiou et al. (2013) propose that saving money on car ownership could motivate low income groups to start with car sharing, provided that incomes are sufficient to cover the car sharing fees. Other research (Aguilera-García et al., 2022) finds that car sharing predominantly attracts higher income groups, even in cases when car sharing offerings were specifically designed to serve lower income households with unmet mobility needs (Leroy et al., 2023; Pan et al., 2022). Initial car ownership may also impact the likelihood to adopt car sharing, with Prieto et al. (2017) finding a positive relation and Dias et al. (2017) stating the opposite. Burghard and Dütschke (2019) discover a specific group over-represented among car sharing users, namely families who use shared cars in addition to owning one car. Adoption factors appear to differ between peer-to-peer (P2P) car sharing, in which private car owners rent out vehicles to other consumers, and other forms of car sharing (Prieto et al., 2017; Priya Uteng et al., 2019; Münzel et al., 2019; Ramos et al., 2023), but further research with larger datasets (Münzel et al., 2019) is needed to understand these differences better.

Besides identifying the characteristics of adopters, another important question relates to what motivates people to adopt. There is an active debate about whether car sharing adopters are motivated by functional, or rather symbolic or idealistic considerations. Lindloff et al. (2014) and Ramos and Bergstad (2021) provide evidence that for car sharing users individual functional motives are more important than idealistic notions. Burghard and Dütschke (2019) and Peterson and Simkins (2019) find that both functional (compatibility with current lifestyles and habits) and symbolic (coherence with social norms) attitudes are important. Other researchers (e.g. Mattia et al., 2019; Schaefers, 2013; Hjorteset and Böcker, 2020; Münzel et al., 2019; Bösehans et al., 2023, Vătămănescu et al., 2023) conclude that attitudes towards the environment play a role in car sharing adoption. However environmental consciousness can also reduce the likelihood of adopting car sharing, if it entails a rejection of car travel per se instead of private car ownership only (Aguilera-García et al., 2022; Burghard and Scherrer, 2022). In markets where car sharing is perceived as novel and technologically advanced (e.g. as it usually involves booking by smartphone), attitudes towards technology and novelty-seeking also impact the adoption decision (Aguilera-García et al., 2022; Vătămănescu et al., 2023).

Some studies have gone beyond correlating car sharing adoption with individual user characteristics, by identifying user segments that are composed from a combination of personal characteristics of users, characteristics of their usage of car sharing, and effects that usage has on outcomes such as car ownership. Reiffer et al. (2019) cluster users of station-based car sharing on characteristics of car sharing usage, such as usage frequency, trip distance, day of the week and vehicle type used, applying k-means clustering. Burghard and Dütschke (2019) also use k-means clustering to segment participants in shared mobility field trials, including a mixture of users of car sharing and pedelec sharing. They cluster users on socio-demographic variables as well as transportation habits (number of transport modes used) and intentions to use shared EV's. Julsrud and Farstad (2020) use latent cluster analysis to segment car sharing users based on a combination of socio-demographic variables, psychosocial motivations for joining car sharing (environmental, utilitarian or economic), access to alternative means of transport, and the purpose, frequency, duration and distance of trips made with shared cars. They identify a segment of environmentally motivated users who use car sharing for a diverse range of trips, and two segments who don't have clearly defined motivations but use car sharing for either local trips or long distance holidays. This study also includes the car sharing business model used as a cluster variable.

Car sharing use can have a number of societal effects. It affects both the production phase, through its impact on car ownership, as well as the

use phase of cars, and hence relates to a range of environmental outcomes including GHG emissions, energy use, materials depletion, air pollution, land take, freshwater eutrophication and acidification (Vélez, 2023). When shared cars replace privately owned cars, a smaller fleet can provide for the same mobility needs. Shared cars are used more intensely and hence have a shorter lifetime. Since they are less affected by calendar aging (depreciation not caused by car use, for example technical obsolescence) they end up driving more kilometers over their lifetime, resulting in a lower carbon footprint than privately owned cars (Morfeldt and Johansson, 2022). Moreover, about one third of the reductions in GHG emission takes place in the use phase, as car sharing users tend to drive fewer kilometers than car owners (Nijland and van Meerkerk, 2017). Reductions in car use also contribute to a host of other societal interests, including less road congestion, fewer traffic fatalities and enhanced livability in cities (Demirbilek and Nawangpalupi, 2008). Shared cars can also be used by households with unmet mobility needs who are unable to own a vehicle (Brown, 2017; Meelen et al., 2019). This contributes to the accessibility of underserved population segments, enhancing social equity. Whether environmental or accessibility-related societal effects dominate depends on the composition of car sharing users: a higher share of users who did not initially own cars, leads to a predominance of accessibility-related effects and lower environmental benefits or even net increases in emissions and other harmful effects of car use (Vélez, 2023; Jung and Koo, 2018; Amatuni et al., 2020, Vejchodská et al., 2023).

Some studies have segmented users of car sharing based on the effects of car sharing. Liao et al. (2020) segment potential car sharing users based on prospective changes in mobility outcomes, namely the willingness of users to replace private car trips by car sharing, and their willingness to use shared cars as an alternative to private car ownership. They regard socio-demographic characteristics and motivations to use car sharing as covariates rather than as class predictors. Jain et al. (2020) also segment car sharing users on outcomes on car ownership, but use qualitative rather than quantitative methods. They segment users based on their car ownership level before starting with car sharing as well as any changes in car ownership that followed. They find examples of users who begin at a higher level of car ownership, and use car sharing to reduce it (car sellers) or prevent further increase (car limiters). Another user segment begins without car ownership, and uses car sharing to avoid having to buy a car in the future (car avoiders). For some segments, car sharing has no impact on their car ownership, as they maintain a high level of car ownership (car dependents) or go on to purchase new cars while using car sharing (car aspirers).

We have seen that the literature so far tends to segment car sharing users on a broad mixture of variable types. This yields very specific and multifaceted user groups, but a drawback of this approach is that the resulting user groups are difficult to match with population statistics since many of these variables require costly surveys to collect. The current study opts instead for a segmentation based solely on socio-demographic indicators, for which population statistics are readily available. Besides this practical reason, segmenting on socio-demographic variables also has a substantive reason as these variables can together capture life phases associated with different mobility needs and drivers for car ownership (Clark et al., 2015). Other facets of car sharing, namely motivations to use car sharing, platform type, membership characteristics and usage characteristics, are then related to these socio-demographic segments in the form of dependent covariates. In this way, this study is the first to combine a comprehensive model of car sharing that can readily be matched with population statistics. It is also the first study to show how effects of car sharing use on mobility outcomes differ by socio-demographic user group. This is important information as it shows whether car sharing has more potential for generating societal benefits in some user groups than in others. Change in car ownership and mode use are included in the model as dependent covariates.

The setup of the model is illustrated in Fig. 1. The socio-demographic

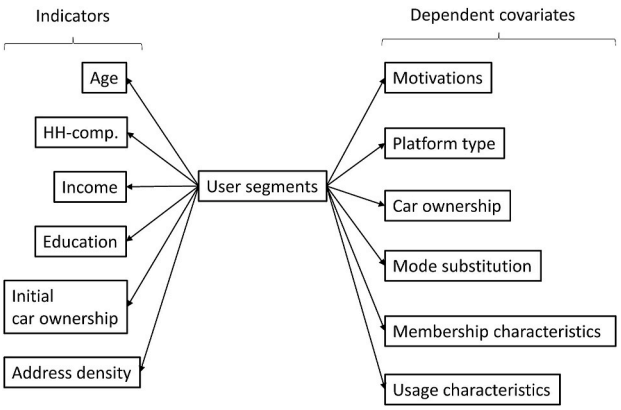

Fig. 1. Conceptual model.

variables used as indicator variables are those that were found to be relevant for consumer adoption of car sharing in previous research. This includes the age (e.g. Becker et al., 2017; Aguilera-García et al., 2022) of car sharing users, as well as their education level (Becker et al., 2017; Aguilera-García et al., 2022), income (Efthymiou et al., 2013; Aguilera-García et al., 2022; Leroy et al., 2023; Pan et al., 2022), household composition (Efthymiou et al., 2013; Burghard and Dütschke, 2019; Kawgan-Kagan, 2020; Aguilera-García et al., 2022; Bösehans et al., 2023), and their initial car ownership before becoming active users of car sharing (Prieto et al., 2017; Dias et al., 2017; Burghard and Dütschke, 2019). Moreover we include the urbanity of the place of residence (Priya Uteng et al., 2019), measured as the address density. The resulting user segments are then related to two mobility outcomes, namely changes in car ownership since engaging with car sharing, and change in mode choice. The operationalization of the other covariates is discussed in section 4.

3. Data and methodology

For the empirical analysis of this study we collected data using a large-scale survey conducted in the Netherlands in the summer of 2018. The survey was completed online by members of the three major car sharing platforms active in the Netherlands. This section introduces the data and explains how the three-step latent clustering method is used to analyze it.

3.1. Data

This study exploits a large-scale nationwide survey of active users of car sharing from the Netherlands. Participants were invited using a personalized email or through the newsletter of their car sharing provider. They were not offered financial compensation, but could enter a raffle with minor rewards when participating. In the Netherlands station-based B2C (B2C-SB) car sharing and P2P car sharing are the most common types of car sharing platforms. Other platform types, such as free floating and cooperative car sharing, are limited in scope and yielded insufficient respondents in our survey to be able to meaningfully include them in our analysis. Therefore, we select three groups of car sharing users from the dataset, namely users of B2C-SB car sharing, users of P2P car sharing, and users of both B2C-SB and P2P car sharing. Moreover, a small number of respondents was not actively using car sharing at the time of the survey, and was omitted from the sample. Finally, we omit incomplete responses, mostly due to respondents who were unwilling to state their income. This results in a dataset of 2010 complete responses (see Table 1). Over two thirds of these responses are from users of B2C-SB users, about 22% are from P2P users, and the remaining 10% are from users who combine B2C-SB and P2P car sharing (see Table 2).

Table 1
Sample size and missing values.

Total sample:	**2652**
..not B2C-SB or P2P users:	*289*
..inactive user:	*61*
Relevant sample:	**2363**
..income not answered:	*334*
..education level not answered:	*15*
..no valid zipcode:	*10*
Complete responses:	**2010**

3.2. Latent variables

To assess whether the socio-demographic user segments also have different motivations for engaging in car sharing, psychosocial variables were constructed to measure potential motivations for becoming an active car sharing user. To this end, respondents were offered eleven attitude statements that were designed to capture both functional (saving costs and time) and idealistic motivations (benefitting the environment and the local community). Using principal component analysis (Varimax) we find that the environmental and social motivations are distinctive latent variables. Instead of a functional motivation variable, we find that a more specific financial motivation variable describes the data best. This is due to the poor fit of the item "car sharing helps me to save time", which we subsequently chose to omit. We thus retain three latent variables, each of which has a Cronbach α above 0.85. Table 3 presents the ten items used (translated from the original Dutch to English), as well as their factor loadings (factor scores below 0.4 are not included). The original items were all measured on a seven point Likert scale. We combine them into three variables by taking the average of the respective items, and then rounding them off to single digits. The resulting motivation variables are ordinal variables on a seven point scale.

3.3. Descriptive statistics

Table 4 gives an overview of all variables used in the latent cluster analysis. Looking at the indicator variables, we see that the respondents have an average age of 47 years old, which is slightly below the Dutch average for driving license holders (CBS, 2018). It is split evenly by household type, which means that single person households are overrepresented and households with children somewhat underrepresented compared to the Dutch average. Higher incomes and education levels are both overrepresented compared to the population, while the sample initially owned fewer cars per household. Note that income was measured at the personal, not the household level, and excludes tax and benefits. The average address density (number of residential addresses within a 1 km radius, measured at the 4 digit zip code level) is substantially higher than the Dutch average, which is a plausible result since car sharing users tend to live in relatively high density places (e.g. Priya Uteng et al., 2019).

Looking at the covariate variables, we see that on average, respondents score highest on the environmental motivation variable (5.8 on a scale of 1–7), followed by the financial motivations. Social motivations were on average scored comparably low at 2.8 out of 7. In terms of usage characteristics, we see that a tenth of the sample uses car sharing at least weekly, and about 50% at least monthly. In the remainder of the analysis we transform the use frequency to a continuous variable, by assigning each level its midpoint value. This results in an average use frequency of about 25 trips per year. Respondents also indicated the trip purposes for which they use car sharing. Eight categories were proposed to the respondents, out of which visits to family and friends and making daytrips were the most commonly selected, followed by business trips, doing groceries or bringing children, shopping, sports and travel to work or school. 18% of the sample uses car sharing for other trips than those listed.

Two membership characteristics were measured, namely the duration (in years) of car sharing membership at the time of the survey, and the stated intention to continue this membership into the future (measured on a seven point Likert scale). The average respondent has been member of a car sharing platform for over 5 years, and believes to be likely or very likely to continue this membership.

Turning to the outcomes of car sharing, we calculate the change in car ownership by subtracting the number of cars per household owned at the time of the survey from the initial car ownership. We observe that the average active car sharing user shed a bit less than one car per two households. Finally, respondents were asked to indicate which transport mode they used before they started with car sharing, for the trips they currently make by car sharing. Note that these mode substitution variables are based on a multiple response question, so car sharing users can substitute more than one mode. About 40% used a private car for (some of) the trips now made by car sharing, over 60% used public transport, and about a third used to walk or cycle when undertaking these trips.

Table 2
Complete responses by platform type.

	N	%
P2P	438	21.8
B2C-SB	1374	68.4
P2P and B2C-SB	198	9.9
Total	**2010**	**100**

Table 3
Motivations for car sharing - Factor loadings. Rotated and sorted component matrix.

	Component		
	Environmental	Financial	Social
Cronbach α	*0.922*	*0.852*	*0.889*
Sustainable form of consumption	0.900		
Environmentally friendly	0.938		
Helps to save natural resources	0.925		
Allows me to save money		0.861	
Gives me financial benefits		0.917	
Improves my economic situation		0.830	
Makes me feel connected to other members			0.895
Allows me to do something good for other members			0.917
Gives me nice interactions with other members			0.891
Enables me to live in a thriving local community			0.756

3.4. Methodology

Latent class analysis is a model-based probabilistic segmentation technique, as opposed to deterministic clustering methods such as K-means clustering. The main benefit of probabilistic assignment is that biases in cluster centers are reduced, because cases that do not readily fit any of the clusters are distributed more evenly across the clusters (Magidson and Vermunt, 2002). In addition, given that it is a model-based technique, statistical criteria are available to determine the optimal number of clusters. A third benefit of the method (compared to e.g. K-means) is that scaling of the variables used (e.g. standardization) is not needed, and that variables of different measurement levels (nominal, ordinal, continuous) can be used simultaneously (Magidson and Vermunt, 2002).

When cluster membership is related to dependent covariates, a correction method needs to be used to avoid a tendency of the algorithm to underestimate associations between cluster membership and dependent variables. For this we use the three step approach (Vermunt, 2010), which offers the BCH method for binary and continuous dependent variables (Bakk and Vermunt, 2016), while for ordinal dependent

Table 4
Variables used – overview and descriptive statistics.

Variable name	Description	Mean	SD
Indicator variables:			
Age	Age in years	47.3	13.7
Household composition	Categorical in three levels:		
	1: single without children living at home	33%	0.5
	2: couple without children living at home	33%	0.5
	3: household with children living at home	34%	0.5
Income	Monthly pre-tax (personal) income, ordinal variable with 8 levels		
	1: Below 1500 euro per month	12%	0.3
	2: 1500–2500 euro per month	19%	0.4
	3: 2500–3500 euro per month	24%	0.4
	4: 3500–4500 euro per month	20%	0.4
	5: 4500–5500 euro per month	11%	0.3
	6: 5500–6500 euro per month	6%	0.2
	7: 6500–7500 euro per month	4%	0.2
	8: More than 7500 euro per month	5%	0.2
Address density	Average number of addresses within 1 km radius of home	4414	2763.9
Education	Categorical in three levels:		
	1: completed scientific education	13%	0.3
	2: completed higher vocational education	33%	0.5
	3: highest completed education is lower vocational or less	54%	0.5
Initial car ownership	Household car ownership before joining car sharing; categorical in three levels:		
	1: no car	53%	0.5
	2: one car	40%	0.5
	3: two or more cars	7%	0.3
Dependent covariates:			
Motivation: social	Ordinal variable in 7 levels: social motivations for car sharing	2.8	1.4
Motivation: environmental	Ordinal variable in 7 levels: environmental motivations for car sharing	5.8	1.2
Motivation: financial	Ordinal variable in 7 levels: financial motivations for car sharing	4.6	1.5
Platform type	Type of car sharing platform used, in three levels		
	1: peer-to-peer	23%	0.4
	2: station-based business-to-consumer	68%	0.5
	3: peer-to-peer and station-based business-to-consumer	10%	0.3
Use frequency	Ordinal variable in 6 levels: frequency of using car sharing	24.5	31.8
	1: 4 or more days per week	1%	0.1
	2: 1–3 days per week	10%	0.3
	3: 1–3 days per month	39%	0.5
	4: 6–11 days per year	28%	0.4
	5: 3–5 days per year	15%	0.4
	6: 1–2 days per year	8%	0.3
Purpose: work/school	1 if using car sharing for travel to work or school, 0 otherwise	7%	0.3
Purpose: business	1 if using car sharing for business travel, 0 otherwise	19%	0.4
Purpose: kids/groceries	1 if using car sharing for bringing children or doing groceries, 0 otherwise	17%	0.4
Purpose: shopping	1 if using car sharing for non-daily shopping, 0 otherwise	15%	0.4
Purpose: sports	1 if using car sharing for travel to sports activities, 0 otherwise	9%	0.3
Purpose: day trip	1 if using car sharing for making daytrips, 0 otherwise	42%	0.5
Purpose: visit friends/family	1 if using car sharing for visiting family or friends, 0 otherwise	63%	0.5
Purpose: other	1 if using car sharing for other travel purposes, 0 otherwise	18%	0.4
Membership_duration	Number of years since becoming a member of a car sharing platform	5.4	5.3
Membership_intention	Ordinal variable in 7 levels: intention to continue car sharing	6.0	1.2
Car ownership change	Change in car ownership per household since joining car sharing	−0.4	0.6
Substitution: car	1 if shared car is used instead of a private car, 0 otherwise	41%	0.5
Substitution: pt	1 if shared car is used instead of public transport, 0 otherwise	62%	0.5
Substitution: walk/bike	1 if shared car is used instead of a walking or bicycle, 0 otherwise	34%	0.5

variables we follow the advice of Vermunt (Personal communication, March 6, 2023), professor of Methodology at Tilburg University, to use maximum likelihood as a correction method. In all models we use robust (sandwich) standard errors, and we report Wald statistics.

4. Results

4.1. Measurement model

We use the indicator variables to estimate solutions from 1 cluster to 10 clusters. Each additional cluster reduces the log likelihood substantially, although by a decreasing share (see Table 5). The BIC values (which penalize for the number of parameters estimated) decrease little beyond an 8 cluster solution. When we inspect the cluster solutions, we can label all clusters meaningfully at a 6 cluster solution, while staring from the 7 cluster solution the clusters start to overlap more and become less recognizable. Therefore, we choose the 6 cluster solution to be used in the remainder of the analysis. All indicator variables show highly significant differences between the classes.

The six clusters of car sharing users are detailed in Table 6 and labelled according to their most distinct features. *Wealthy Families* is the largest cluster, representing a third of the sample. It is dominated by households with children living at home, and shows the strongest overrepresentation of high incomes (personal pre-tax income above 3500 euro per month). The second largest cluster, *50+ without kids*, shows the highest average age and an almost complete absence of children living at home. The *Working Class* cluster has a clear overrepresentation of lower and medium incomes, and people with lower vocational education or less. They also show the lowest average address density. *Car-free Yuppies* are young, highly educated urbanites without children, who predominantly did not own cars already before starting with car sharing. The *Inner City Dwellers* are also relatively wealthy and highly educated, and are characterized by an extremely high address density only found in the most densely populated urban districts. Finally, the smallest cluster consists of *Young Singles* - graduates or students, most of whom live alone and earn medium to low incomes.

Table 5
Model fit - LL and BIC of measurement model.

Nr. of clusters	BIC	-2LL	% reduction in -2LL (vs 1-Cluster)
1	73510	73381	0.00
2	72921	72716	0.91
3	72418	72137	1.69
4	72159	71802	2.15
5	72012	71579	2.46
6	71932	71422	2.67
7	71882	71306	2.83
8	71828	71167	3.02
9	71815	71077	3.14
10	71807	70993	3.25

Table 6
Characteristics of car sharing user segments.

	Wealthy Families	50+ without Kids	Working Class	Car-free Yuppies	Inner City Dwellers	Young Singles	Wald	Sig.
Cluster size (%)	33	18	17	14	14	5		
Initial car ownership							52.6	***
no car (%)	43	40	43	93	54	79		
one car (%)	48	50	48	7	41	20		
two or more cars (%)	9	11	9	0	5	1		
Age	45.7	62.8	51.7	30.2	51.6	24.0	1770	***
Household composition							118.2	***
single without children (%)	17	37	41	37	33	92		
couple without children (%)	16	62	27	56	30	3		
household with children (%)	67	2	32	7	38	4		
Income[a]							53.3	***
below 1500 (%)	3	6	24	12	5	61		
1500–3500 (%)	31	42	59	53	39	37		
above 3500 (%)	66	52	17	35	56	2		
Address density	3643	3929	2184	5191	9344	3234	466.1	***
Education							42.4	***
lower vocational or less (%)	5	8	42	3	9	29		
higher vocational education (%)	29	34	42	25	35	44		
scientific education (%)	67	58	16	72	56	26		

*p < 0.05; **p < 0.01; ***p < 0.001.
[a] Income was modeled as an ordinal variable with 8 levels. For clarity we here reduce the outcomes to three levels.

4.2. Dependent covariates

4.2.1. Motivation

When we look at the dependent covariates (Table 7), we see first of all that clusters hardly differ in the relative importance of the three motivation variables. Values do show a statistically significant difference by cluster, but do not differ substantially in a real-world sense (see Fig. 2). Car sharing users in all six clusters value sustainability motivations most strongly, with little difference between the clusters. Financial motivations have an intermediate level of importance for all six segments of car sharing users, while social motivations have the lowest importance for all six clusters.

4.2.2. Platform type

User segments differ significantly in their preference for different types of car sharing platform (see Fig. 3). While for all segments B2C is the dominant form of car sharing, we see that for three user segments, namely *Working Class*, *Car-free Yuppies*, and *Young Singles*, P2P car sharing also contributes a substantial share of users. Those users who are a member of both a P2P and a B2C platform represent a small share of each cluster, and are least common among the *Working Class* and *Young Singles* clusters.

4.2.3. Usage characteristics

The frequency of using car sharing is borderline significant (p-value 0.052). We see the highest use frequency for *Wealthy Families* (over 31 trips per year), while the *Working Class* and *Car-free Yuppies* segments make on average fewer than 14 trips per year. The six user segments differ significantly in the trip purposes for which they use car sharing. *Wealthy Families* are the most all-round users, with relatively high likelihood to undertake most of the trip purposes. *Young Singles* are the most likely to use car sharing for their journey to work or school, and the least likely for visiting family or friends. All segments except *50+ without Kids* show a high proportion of using car sharing for daytrips.

4.2.4. Membership characteristics

Membership duration shows highly significant differences among the six user segments. The *Car-free Yuppies* and *Young Singles* have on average been a car sharing member for only about a year. This could be due to their relatively young age, as some car sharing platforms have a minimum age requirement of 21 years old, and/or require one to hold a driver's license for at least a year. The *Working Class* segment also shows a relatively short membership duration, even though this segment is slightly older than the average in our sample. It seems that this segment has turned to car sharing relatively recently. The oldest segment, *50+*

Table 7
Results for dependent covariates.

	Wealthy Families	50+ without Kids	Working Class	Car-free Yuppies	Inner City Dwellers	Young Singles	Wald	Sig.
Motivation: social	2.5	3.1	3.5	2.4	2.7	2.9	88.1	***
Motivation: environmental	5.9	6.1	5.6	5.6	5.7	5.2	33.4	***
Motivation: financial	4.7	4.6	4.6	4.3	4.8	4.2	20.8	***
Platform type							139.0	***
P2P (%)	15	4	42	36	11	48		
B2C_SB (%)	71	89	55	51	79	49		
P2P + B2C_SB (%)	14	7	3	13	10	3		
Use frequency	31.3	27.9	13.9	13.7	28.9	21.1	11.0	
Membership duration	5.8	9.5	3.8	1.2	7.1	0.8	1109.6	***
Membership intention	6.0	6.4	5.7	5.8	6.0	5.9	16.9	**
Purpose: work/school (%)	7	3	9	4	7	17	16.5	**
Purpose: business (%)	25	19	15	13	20	12	21.1	***
Purpose: kids/groceries (%)	26	13	9	9	18	18	38.1	***
Purpose: shopping (%)	14	16	9	23	17	15	15.3	**
Purpose: sports (%)	14	5	1	6	11	10	19.5	**
Purpose: daytrip (%)	43	23	42	56	45	59	59.0	***
Purpose: visit friends/family (%)	66	69	58	54	72	34	48.9	***
Purpose: other (%)	13	25	21	18	16	22	17.5	**

*p < 0.05; **p < 0.01; ***p < 0.001.

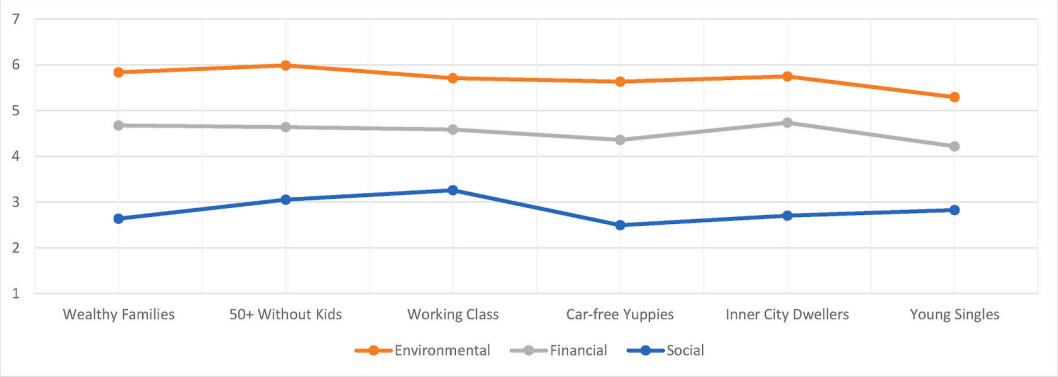

Fig. 2. Scoring of motivations by user segment.

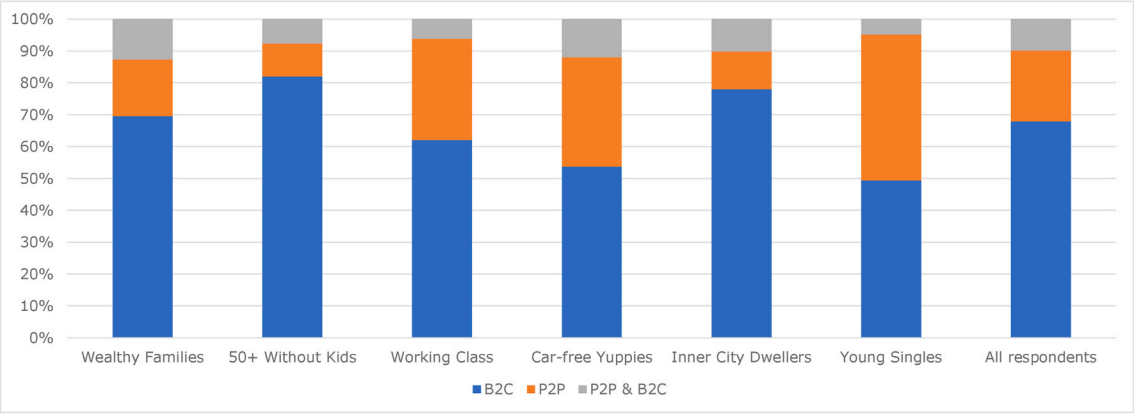

Fig. 3. Platform type shares by user segment.

without kids, has been a car sharing user for on average almost 10 years. Intentions to continue car sharing were high among all segments, with the highest score for *50+ without kids*.

4.3. Effects of car sharing on car ownership and mode choice

We now turn to the dependent covariates which measure the effects that car sharing has on outcomes with societal relevance. Each of these variables show highly significant differences between the user segments (see Table 8).

Changes in car ownership differ significantly between clusters. Members of two clusters (*Car-free Yuppies* and *Young Singles*) see hardly any reduction in car ownership, or even a small increase. This can be explained by the very low rates of car ownership of these segments at the time of joining a car sharing platform. The other four clusters substantially reduce their car ownership, with the strongest effect for the cluster *50+ without Kids*. The effects range from more than 1 car shed for every three households (*Wealthy Families*, *Working Class*, *Inner City Dwellers*) to almost 2 cars shed for every three households (*50+ without Kids*)

We also see significantly different patterns of mode substitution between the user segments. The two segments with low initial car ownership (*Car-free Yuppies* and *Young Singles*) show substantially higher probabilities than the other segments of substituting public transport, or using car sharing instead of walking or cycling.

5. Discussion

Our results provide new insights into the factors that play a role in the consumer adoption of car sharing, by employing a comprehensive user segmentation method. As intended, the user segments produced with this method reflect distinct life phases, which earlier research has shown to correlate with different mobility needs and drivers for car ownership (Clark et al., 2015). In line with Kim et al. (2019), we find that car sharing has moved beyond the original niche of young, highly educated workers (Becker et al., 2017, Aguilera-García et al., 2022). In our sample, users in their twenties and early thirties represent relatively small segments, while households close to or above retirement age are the second largest user segment. In line with previous research, we find an overrepresentation of users with higher education and income (Aguilera-García et al., 2022; Leroy et al., 2023; Pan et al., 2022) living in highly urbanized areas (Priya Uteng et al., 2019). But our segmentation method also reveals a substantial segment with medium to lower

Table 8
Changes in car ownership and mode choice by user segment.

	Wealthy Families	50+ without kids	Working class	Car-free yuppies	Inner city dwellers	Young singles	Wald	Sig.
Car ownership change	−0.37	−0.63	−0.48	0.05	−0.38	−0.04	193.7	***
Substitution: car (%)	49	56	50	0	40	19	1498.0	***
Substitution: pt (%)	59	54	50	93	58	79	69.2	***
Substitution: walk/bike (%)	30	34	36	44	28	47	24.6	***

*p < 0.05; **p < 0.01; ***p < 0.001.

incomes and education levels, living in lower density suburban neighborhoods (the *Working Class* segment). Finally we find that car sharing both attracts households without children (*50+ without Kids, Car-free Yuppies* and *Young Singles*), as suggested by Efthymiou et al. (2013), and families with children living at home (*Wealthy Families*), in line with Burghard and Dütschke (2019), Bösehans et al. (2023) and Kawgan--Kagan (2020). In sum, by looking beyond average user characteristics, we find a diverse range of car sharing users with contrasting socio-demographic characteristics.

User segments with different socio-demographic characteristics, also differ in the way they use car sharing. *Wealthy Families* have the highest use frequency and are the most all-round users in terms of trip purposes. The segments of the *Working Class*, *Car-free Yuppies* and *Young Singles* show a lower use frequency and joined car sharing relatively recently. *Young Singles* are the most likely to use car sharing for their journey to work or school, and the least likely for visiting family or friends. All segments except *50+ without Kids* show a high proportion of using car sharing for daytrips. Finally, intentions to continue car sharing are strong among all segments, with the highest score for *50+ without Kids*.

In line with the literature (Vejchodská et al., 2023, Vélez, 2023), we find that the societal effects of car sharing depend strongly on the initial level of car ownership of car sharing users. The strongest reductions in car ownership were found for user segments with relatively high car ownership rates at the time of joining car sharing (*50+ without Kids* and *Working Class*). User segments with little to no initial car ownership (*Car-free Yuppies* and *Young Singles*) show no noticeable reductions in car ownership, and also indicate the highest likelihood among all segments to substitute public transport. They particularly use car sharing for making daytrips and visits to friends and family. For these users, car sharing is unlikely to generate positive environmental impacts, but it presumably enhances their accessibility. However the results cannot show whether users without initial car ownership make more trips thanks to their access to shared cars, or whether they were mobility-deprived before joining car sharing.

This paper also adds to the discussion on psychosocial motivations for adopting car sharing, by showing that for active car sharing users environmental motivations take precedence over functional motivations. This finding is in line with Mattia et al. (2019), Schaefers (2013), and Hjorteset and Böcker (2020), and in contrast to Lindloff et al. (2014) and Ramos and Bergstad (2021). We also test the potential role for social motivations, but find them to play no substantial role in the adoption decision. We deepen the analysis by exploring whether the relative importance of psychosocial motivations for car sharing differ by user segment, but found no substantial differences. User segments do differ substantially in their preference for different types of car sharing platform. This is in line with Priya Uteng et al. (2019), who showed that users of P2P car sharing differ in demographic characteristics and recent life events.

6. Conclusion

This study applies latent class analysis to a nation-wide dataset of car sharing users from the Netherlands, in order to discover user segments based on socio-demographic characteristics. The segmentation based on age, income, education, household composition, car ownership and urbanity of the place of residence results in six clusters, which reflect distinct life phases. It reveals that car sharing is adopted by a wide range of users, from adolescents to seniors, from singles to families with children, and from working class to high income households. One third of the analysed Dutch car sharing users are assigned to the cluster *Wealthy Families*, followed by another third that belong to the clusters *50+ without Kids* and *Working class*. The final third of car sharing users belongs to two clusters with young users (*Car-free Yuppies* and *Young Singles)*, and one cluster with residents of highly urban areas (*Inner City Dwellers*). We conclude that a comprehensive user segmentation can be made based on socio-demographic variables.

With the three-step method we then show how the resulting clusters are associated with a range of covariates. We find that user segments do not differ substantially in terms of their motivations to adopt car sharing. Across all segments sustainability related motivations are most important, followed by cost-saving. Social motives are least recognized by all segments. Car sharing users perceive car sharing as a way to save money, but not to save time. The user segments differ in their propensity to choose P2P car sharing, station-based B2C car sharing, or a mix of the two. In our sample and the resulting user segments, station-based B2C car sharing represents the main service used. Still, three segments (*Working Class*, *Car-free Yuppies* and *Young Singles*) also show a substantial share of P2P car sharing users. Finally the clusters differ strongly in the societal effects that result from their use of car sharing. Segments with high initial levels of car ownership (*50+ without kids*, followed by *Wealthy Families, Working class and Inner city dwellers*) tend to reduce the number of cars in their household when they use car sharing, while two segments were identified that do not noticeably reduce car ownership and are more likely to substitute away from public transport use (*Car-free Yuppies* and *Young Singles*).

The results provide actionable insights for practitioners. The segmentation method is based on readily available statistics, and can be used by car sharing providers and stakeholders who want to promote the upscaling of car sharing. The insights can be used to inform efforts to mobilize potential users to join car sharing, specifically targeting the neighborhoods where potential user groups live. Moreover the results help to anticipate which form of car sharing (i.e. station-based B2C, P2P car-sharing or both) these potential users would adopt, and what the characteristics of their car use will be. For example, differences in use frequency among user groups have implications for the number of shared cars needed to cater to their demand, while differences in the trip purposes for which target groups use shared cars can be taken into account when deciding what type of cars to offer (e.g. cars with longer electric driving range in neighborhoods where daytrips are an important trip purpose). Moreover, the study shows that some user segments could be targeted specifically if the goal is to achieve environmental effects, through reduced car ownership and use. If enhancing the accessibility of households without access to a car is (also) considered as a policy goal, segments with already low car ownership can also be specifically targeted. However this may dampen the overall environmental benefits of stimulating car sharing, and could come at a cost to public transit ridership.

A limitation of this study is that the findings specifically apply to users of station-based B2C car sharing and P2P car sharing. Other forms of car sharing, such as free floating and cooperative car sharing, are not widespread enough in the Netherlands to yield a sufficient sample size without oversampling them. Generalizability of our findings to such other forms of car sharing is likely to be limited, given that earlier research found that free floating car sharing (e.g. Becker et al., 2017; Lempert et al., 2019) and cooperative car sharing (Priya Uteng et al., 2019) attract quite different user groups and are used for different trip purposes than the forms studied here. Further research could explore whether the user segments identified in this research also apply for other forms of car sharing. Another limitation is that, while an extensive number of attitude statements was collected, it does not cover all relevant psychosocial variables proposed in the literature. Besides environmental, functional and social motivations for adopting car sharing, attitudes towards technology and novel products can also influence the adoption decision (Aguilera-García et al., 2022; Vătămănescu et al., 2023) and could be explored further in future research.

The analysis of changes in car ownership induced by the use of car sharing is limited to what Shaheen et al. (2012) call the observed effect, namely the change in the number of cars owned by a household. Car sharing can also affect car ownership by suppressing vehicle purchases, for example for a household that was already carless to remain carless or a household with a single car to not purchase a second one. Such unobserved effects on car ownership could not be measured using the data

available for this research. Moreover, while we assume that car sharing plays a role in the decisions of car sharing users on car ownership, we cannot exclude the possibility that other factors such as unmeasured life events or changes in the built environment are also involved. Further research could combine user segmentation with a more complete measurement of (potential) changes in car ownership, as well as control for other simultaneous factors that could explain car shedding. Moreover, further research could investigate whether the availability of carsharing in some neighborhoods induces residential self-selection, attracting households who prefer to own fewer cars.

In terms of the data used for this study, a limitation is that the data was collected before the COVID-19 pandemic, which means that any changes that occurred since then are not reflected in the outcomes. Moreover, a limitation of the survey used for data collection is that respondents could only indicate for which transport mode they substitute car sharing, not whether trips made through car sharing would have been made in the first place. Further research could investigate to what extent access to car sharing leads to new trip generation. This would also help to understand societal effects related to accessibility and equity, as the generation of new trips combined with indicators of unmet mobility needs would be needed to understand such societal effects better. In terms of environmental effects of car sharing, this study did not consider potential rebound effects (Amatuni et al., 2020, Vélez, 2023) in case financial savings from car sharing lead to increased consumption of other goods. An avenue for further research would be to research whether such potential rebound effects differ by car sharing user group.

As car sharing continues to evolve, its user segments are likely to change over time. An interesting avenue for further research would be to test whether the same user groups as identified in this research can also be used to segment more recent user data, or whether new user groups have engaged with car sharing in the meantime. As the segmentation method applied in our study only requires frequently measured variables, older datasets may also be suitable for being reanalyzed to reveal user segments from earlier time points and hence to map out the evolution of the car sharing user base.

CRediT authorship contribution statement

Jan-Jelle Witte: Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Lukas Kolkowski:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Nicole Stofberg:** Writing – review & editing, Data curation. **Bert van Wee:** Writing – review & editing, Supervision. **Maarten Kroesen:** Writing – review & editing, Supervision, Methodology.

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Declaration of competing interest

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Data availability

The data that has been used is confidential.

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