Driving factors behind station-based car sharing use in the Netherlands

Discovering distinct user profiles through a Latent Class Cluster Analysis

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by

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Preface

This study is the final product of my graduation project which started seven months ago. This study also finalises my study time in Delft. When I started my bachelor's in 2016, I didn't think of spending more than half a year studying car sharing. However, while it sometimes felt like a never-ending process, most of the time it was a really nice and fun journey in which I learned a lot on the topic, but also about myself and managing my own project.

This study would not have been as it is without the help of some people. Therefore, first of all, I would like to thank Suze en Martijn of Goudappel for guiding me through the entire process and giving me the freedom to shape my own study. Furthermore, I would like to thank the other colleagues at Goudappel for the warm welcome and all the fun and inspiring conversations we've had.

I would also like to thank Anja and Colin from Greenwheels, who provided me with the opportunity to work with actual car sharing data and provided me with some novel insights from a car sharing company's perspective.

In addition, I would like to thank my supervisors Maarten Kroesen and Goncalo Correia for always making time for me when I asked for it and for providing valuable feedback on my work. I would also like to thank Niels van Oort for inspiring me to study something on the topic of shared mobility and for guiding me through the graduation process.

Finally, I want to express my gratitude to my family, friends, and girlfriend for supporting me not just for the last seven months, but throughout my entire study period.

I hope you enjoy reading it!

Hidde van der Linden
Delft, October 2023

Summary

In light of growing environmental challenges, the need to reconsider how we approach personal transportation becomes increasingly evident. Private cars take up 55% of the available public street space in the 20 largest Dutch municipalities while on average they remain parked 96% of the time. With limited public space available in urban areas, a reduction in car ownership is often desired by governmental institutions. To this end, shared cars might prove essential in transitioning to a more sustainable and equitable transportation system that no longer prioritises private cars. The existing car sharing market, while promising, remains a niche, which raises the question for both car sharing operators and governmental institutions on how to successfully stimulate sustainable transportation through the use of car sharing services. However, there appears to be a lack of comprehensive knowledge regarding the factors influencing the actual usage of station-based car sharing services. In particular, there is a tendency in scientific literature to treat car sharing users as a homogeneous group overlooking potential variations caused by individual differences. This generalisation of the car sharing population overlooks the fact that varying motives for using car sharing may have different impacts individuals' travel behaviour which may lead to varying car sharing impacts. Therefore, this study focused on revealing distinct usage profiles to gain a thorough understanding of car sharing utilisation and its impact in terms of sustainability. To do so, a comprehensive approach towards usage has been adopted, including socio-demographic characteristics, spatial aspects, socio-psychological factors, and actual car sharing usage data. This results in the following main research question:

Which different car sharing user profiles can be identified among car sharers in the Netherlands considering a comprehensive approach towards car sharing usage, and how do these user profiles impact sustainable and equitable transportation?

In addition to the main research question, this study examines the differences between car sharers based on varying membership lengths. The aim is to determine whether new members of car sharing services have distinct characteristics from those who have been members for a longer period. These potential differences may provide insights into the potential expansion of car sharing beyond its traditional niche. Additionally, the study investigates the relationship between car sharing usage and the transportation modes substituted by car sharing, as well as the purpose of car sharing trips. The relations provide valuable insights into how car sharing affects individuals' travel behaviour.

To answer these research questions, car sharing data are needed. These data were gathered through the distribution of a survey among members of the station-based car sharing company Greenwheels. In this survey participants were, among other things, asked about their motives for car sharing and the impact car sharing has had on their car ownership and car use. The survey data was combined with actual data about the number of reservations and car sharing kilometres driven by the respondents. The survey was sent to 13573 members between the 4th and 16th of July 2023 and in total 1393 responses were gathered, resulting in a response rate

of 10.3%. After cleaning the data, 1281 valid responses remained. Besides an underrepresentation of young respondents and a slight overrepresentation of single-person households, the sample is considered a good representation of Greenwheels members.

To answer the main research question, a Latent Class Cluster Analysis (LCCA) was conducted with the software package LatentGOLD®5.1. An LCCA is a model-based probabilistic clustering method which can be used to identify distinct groups, in this case station-based car sharers, that are similar based on certain observed characteristics. To determine which characteristics should be considered, comprehensive literature research was conducted to identify the factors influencing car sharing use from a user perspective. Based on the identified factors, a conceptual model for car sharing use was created. This model includes the determinants that influence an individual's car sharing use, which in this study is operationalised as the number of reservations made by an individual. Through the LCCA, the following six distinct user groups were identified:

- Cluster 1: Moderately motivated car sharers (32% of the sample)
- Cluster 2: Utility-focused car sharers (23% of the sample)
- Cluster 3: Environmentally motivated frequent car sharers (19% of the sample)
- Cluster 4: Highly conscious car sharers (12% of the sample)
- Cluster 5: Environmentally-sceptic utility-focused car sharers (7% of the sample)
- Cluster 6: Sceptical occasional car sharers (7% of the sample)

The complete profiles of the identified clusters can be found in Table 1. This segmentation of station-based car sharers shows how six user groups differ in their motives for using car sharing and their related characteristics. For instance, based on their motives, environmentally motivated frequent car sharers and highly conscious car sharers seem to make a deliberate choice to use car sharing services. Their relatively high level of car sharing use and the substantial reductions in car ownership indicate they primarily use shared cars as a replacement for private car use.

Conversely, environmentally-sceptical utility-focused car sharers have a substantial lower impact on car ownership due to their already low initial car ownership. Encouraging this group to use car sharing may, on one hand, lead to increased car use, but on the other hand, it could enhance transportation equity as formerly car-less people are enabled to use a car when they need one. The other, more substantial, utility-focused group shares similarities with the environmentally-sceptical utility-focuses car sharers. However, members of this group are less sceptical in regard to the environmental motives and more individuals in this group disposed of a car as their initial car ownership was higher. Overall, it can be concluded that for both groups, the shared car is mainly regarded as a useful addition to their mobility options. Therefore, the positive impacts on car ownership and use are relatively less substantial.

Table 1: Profiles of the identified clusters

	Cl.1	Cl.2	Cl.3	Cl.4	Cl.5	Cl.6	Sample
Cluster size	32%	23%	19%	12%	7%	7%	
Indicators (mean)							
Usage frequency	2.52	2.62	2.79	2.62	2.55	2.29	2.59
Environmental motives							
Reduce emissions	2.97	3.20	3.98	4.15	1.50	1.55	3.15
Reduce traffic	3.34	3.78	4.55	4.95	1.40	1.41	3.59
Create public space	2.99	3.24	3.95	4.68	1.32	1.32	3.20
Utility motives							
Cheaper than a private car	4.19	4.88	4.26	4.85	4.85	3.81	4.46
Easier than a private car	3.67	4.73	3.80	4.92	4.62	2.73	4.09
Improves trip quality	3.41	3.91	3.50	4.14	4.17	2.88	3.65
No parking search	2.81	3.49	2.94	4.15	2.81	1.68	3.07
Social motives							
Influence of others	2.77	3.20	2.80	3.71	2.80	2.01	2.94
Joy of driving	2.77	2.85	2.65	3.03	2.71	2.55	2.78
Sharing of goods	3.25	3.69	4.16	4.41	2.80	2.37	3.57
Experienced effort to use							
Use is easy	3.87	4.72	4.34	4.82	4.64	3.67	4.31
Proximity to shared car	4.05	4.98	4.59	4.92	4.91	3.83	4.51
Shared car not available	3.23	2.13	2.84	2.46	2.22	3.24	2.74
Public transport motives							
As last-mile solution for a train trip	2.04	2.02	2.35	2.41	1.66	1.50	2.08
Instead of insufficient PT	4.27	4.52	4.59	4.75	4.44	3.95	4.44
Active covariates							
Age *(mean)*	50	54	53	57	48	48	52
Membership length in months *(mean)*	66	99	96	99	89	49	83
Household size *(%)*							
1	27	36	19	29	33	32	29
2	40	45	42	44	40	37	42
3	15	12	12	11	12	14	13
4+	18	7	27	15	16	17	17
Mean	2.3	1.9	3.1	2.2	2.3	2.2	2.3
Parking facility available *(%)*							
Paid/permit on-street parking	50	74	52	78	71	38	60
Free on-street parking	33	17	26	18	15	32	25
Private parking spot	16	8	21	5	11	30	14
Other	1	2	1	0	2	0	1
Inactive covariates							

Car ownership *(%)*							
0	80	92	90	95	89	68	86
1	19	7	10	5	11	28	13
2+	1	1	1	1	0	3	1
Car disposed after car sharing *(%)*							
0	74	73	66	59	85	70	71
1	26	26	33	40	13	27	28
2 or more	0	1	1	1	1	3	1
Education *(%)*							
None/primary education	0	0	1	1	0	0	0
Secondary education/MBO1	7	7	5	5	8	8	6
MBO2-4	5	6	5	6	5	5	5
HBO/WO	82	84	86	85	87	79	84
I would rather not say	6	3	3	3	0	8	4
Residential Density *(%)*							
Very highly urban	67	85	73	85	86	66	76
Highly urban	25	11	19	11	9	23	18
Moderately urban	4	3	5	4	3	9	4
Little urban	2	1	2	0	2	0	1
Non-urban	1	0	0	0	0	2	1
Main car sharing trip purposes (*% answered yes*)							
Groceries/shopping	22	23	16	15	20	28	21
Visiting friends/family	61	67	70	72	72	60	66
Sports/hobby/entertainment	19	15	20	17	24	19	18
Vacation or weekend trip	32	28	30	33	20	11	25
Going from and to work or study	14	10	15	11	15	14	13
Picking-up/dropping-off goods	55	58	30	56	54	50	56
(Health)care	4	5	3	6	4	4	4
Other	5	5	5	4	5	10	6
Car sharing trip substitution *(%)*							
Shared car from other company	8	10	8	8	8	10	9
Car from family/friend/acquaintance	11	8	10	7	8	12	10
Private car	25	19	31	24	17	32	25
Ride along with someone else	8	9	5	10	9	9	8
Public Transport	33	40	36	41	49	23	36
(E-)bike	7	5	3	5	2	8	5
I would not have made the trip	5	5	5	1	5	3	4
Other	3	4	2	3	1	3	3
Car use after car sharing *(%)*							
More	28	31	23	20	45	19	27
Equal	34	30	35	34	34	46	34
Less	38	40	42	46	21	35	39
Car sharing kilometres *(mean)*	877	940	1270	1146	1018	703	996
Number of reservations *(mean)*	18.8	20.5	23.3	22.6	20.4	17.7	20.6

Furthermore, the sceptical occasional car sharers demonstrate that cost benefits and perceived public transport insufficiency are enough to motivate individuals to dispose of private cars, even with lower levels of car sharing use. Moreover, the relatively high level of car ownership still present in this group indicates that also second cars were disposed of, exemplifying an impact of car sharing, which was not found for the other user groups. These findings hold to a lesser degree also for the moderately motivated car sharers, in which similar patterns were found.

In conclusion, the results of the LCCA highlight that exist one specific type of car sharer does not exist and that implications of stimulating car sharing use may differ per group. Car sharing companies and policymakers should recognise these differences when designing strategies to promote car sharing use or enhance sustainable transportation.

Regarding the potential differences between car sharing members with varying membership lengths, this study found that new members tend to have lower levels of education and reside in less densely urban areas compared to their long-term counterparts. Furthermore, long-term members seem to be slightly more motivated through environmentally and utility-related aspects. Moreover, they seem to experience slightly less effort to use shared cars and hold even stronger motives to use shared cars complementary to insufficient public transport. Lastly, while new members showed lower car sharing use, their intention to use it more often in the future is significantly higher than that of long-term members. Together with only 10% of the new members indicating that their future use will decrease, it suggests that most new members will remain car sharing member in the future. However, while these findings suggest that a greater variety of individuals are being attracted to car sharing, it has to be noted that this study data only reflects a single moment in time. To assess whether the findings are true, longitudinal car sharer data is needed.

Additionally, the relationships of car sharing use with modal substitution of the car sharing trip and the trip purpose provided some key insights. First of all, in line with earlier findings in the literature, the station-based car sharers primarily use the car for occasional trips. However, as usage frequency increases, more routine trips are observed. Furthermore, weighing the hypothetical mode substitution of car sharing trips for car sharing use showed that mostly private car trips are replaced. This differed from the unweighted results, where most individuals indicated they would have used public transport. As car sharing usage intensifies, private car substitution increases while public transport substitution decreases. This underscores the complementary nature of shared cars to public transport, especially given the high public transport use among station-based car sharers compared to the Dutch average.

This research also has its limitations that should be acknowledged. For example, the underrepresentation of young people in the sample might have influenced the results as young people may have different motives for using shared cars, especially concerning the environmental and cost-related aspects. Furthermore, including car sharing use in the LCCA as a categorical variable instead of using the count of reservations resulted in less variation in car sharing use between the clusters. In addition, including each motive for using shared cars as a separate indicator resulted in remaining correlations between the indicators in the final model, violating the assumption of local Independence. This might have caused bias in the cluster outcome and

therefore future research could consider reducing the number of correlated indicators by using a factor analysis prior to the LCCA.

The results of this research can provide helpful guidance for car car sharing companies and governmental institutions. For instance, considering the desire to reduce car ownership in urban areas, governmental institutions should focus on increasing the amount of car sharer, rather than increasing the frequency of car sharing use. This is supported by the fact that the impact on car ownership reduction is substantial for all users, even for more sceptical and occasional users. In addition, as shared cars are found to be a useful but necessary supplement to public transport for car-less individuals, governments could explore ways to improve and stimulate the use of both modes next to each other, to satisfy the travel needs of car-less individuals. This particularly applies to public transport users who retain a car for occasional trips that could potentially be replaced by a shared car.

Besides governmental institutions, car sharing companies could exploit the identified user groups of this research by advertising the specific strengths and benefits of shared to the different (potential) user groups. For example, for utility-focused groups, the perceived benefits in terms of convenience, costs and having an extra transportation option should be mentioned while for the environmental and highly conscious car sharers, the sustainable image should be promoted. In addition, they should consider targeting groups with low private car use by promoting the cost-benefits of car sharing compared to a private car.

Future research could focus on assessing the environmental impacts of the identified distinct user groups and their travel behaviour in more detail. Furthermore, conducting similar research among users of free-floating and zone-based car sharing services would put these results into perspective and would reveal if similar user groups with related motives exist. In addition, future research could focus on clarifying relations between stricter parking policies, the decision to become a car sharer and car ownership. Lastly, future research could examine whether car sharing is actually attracting a greater diversity of individuals by using longitudinal car sharer data. This would also enable assessing how individuals' motives might change over time and whether this influences the identified user groups.

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1 Introduction

1.1. Research context

Over the past decade, interest in the sharing economy has grown enormously, and its applications have become increasingly more visible in our daily lives (Hossain, 2020). Widely known examples are Airbnb and Uber, which have millions of users worldwide. Reasons for the increased interest are that the sharing economy addresses the underutilization of certain assets by sharing those to improve efficiency and sustainability (Hossain, 2020). A specific domain where the sharing economy has received more interest is transportation. Shared mobility is spreading over the world, changing the transportation system of cities by enhancing accessibility while at the same time offering the potential to reduce congestion, emissions and the scarcity of public space (Hossain, 2020; Roukouni & Correia, 2020; Shaheen et al., 2016). With many countries facing challenging sustainability goals and increasing issues regarding the liveability of cities, governments and institutions are acknowledging the need to shift from a private car-focused mobility system towards a more sustainable and equitable transportation system (Greendeals, n.d.). As shared mobility offers travellers new (sustainable) alternatives without having to purchase a vehicle, the need to own a vehicle becomes redundant. This makes shared mobility a transportation system which could contribute to a more sustainable and equitable future regarding mobility.

When it comes to shared mobility, there is a specific emphasis on car sharing. In this study, car sharing refers to the sharing of vehicles between individuals rather than the sharing of rides. The focus on car sharing is due to its association with lower car ownership and usage rates (Kolleck et al., 2021; Nijland & van Meerkerk, 2017). The desire of many governments to reduce car ownership and usage can be illustrated by the fact that cars nowadays occupy most of the public space available in cities. When focusing on the Netherlands, it can be seen that in the 20 largest Dutch municipalities, around 55% of the available public street space is reserved for cars, of which 10% alone is used by parking facilities (van Liere et al., 2017). Combined with the fact that private cars are often parked 96% of the time (Zijlstra, Witte, et al., 2022), a reduction of car ownership and usage in highly urban areas can indeed be considered desirable to create space for other, more sustainable, purposes. Besides these aforementioned potential benefits of car sharing, the literature suggests that car sharing might have a positive impact on modal choice, vehicle kilometres travelled, emissions of Greenhouse Gasses and the accessibility of formerly carless households (Shaheen et al., 2019).

When examining how car sharing is developing in the Netherlands, it is noticeable that a twofold increase in car sharers has occurred since 2014 (Jorritsma et al., 2021). However, at the same time, the share of car sharing trips of the total amount of car trips has not grown since 2014 and is still very limited (0.02%) (Jorritsma et al., 2021). This raises the question

for car sharing companies and governmental institutions of how to effectively increase the use of car sharing services in such a way that it can contribute to the potential benefits associated with car sharing. However, to create effective strategies, it is important to understand what motivates individuals to use car sharing services and which aspects are related to higher and lower car sharing use.

This research aims to reveal what motivates car sharers to use shared cars and if different user groups exist among car sharers. Gained insights could provide meaningful information to create effective strategies for both car sharing companies and governmental institutions to stimulate car sharing in such a way that it will contribute to a more sustainable and equitable transportation system.

1.2. Research problem and gap

The first known car sharing program was established in Switzerland in 1948, but it was in the 1990s that car sharing programs became a permanent phenomena worldwide (Becker et al., 2017; Ferrero et al., 2018). The increased popularity of car sharing has led to significant academic interest. Many studies have focused on the various impacts associated with car sharing, the adoption of different car sharing services, and objective car sharing usage data (Amirnazmiafshar & Diana, 2022; Burkhardt & Millard-Ball, 2006; Hjorteset & Böcker, 2020; Nijland & van Meerkerk, 2017; Reiffer et al., 2019). Many of these studies have provided useful, but also contradictory, insights in car sharing use. However, substantially fewer studies have approached car sharing usage from a user perspective. Especially the inclusion of socio-psychological aspects, such as different user motives, in explaining actual car sharing usage is often neglected.

Studies on the adoption of car sharing services provide helpful information about potential new users. The most mentioned factors positively influencing the intention to use car sharing are having a higher education, being of younger age, and residing in dense urban areas in small households (Aguilera-García et al., 2022; Burghard & Dütschke, 2019; Ceccato & Diana, 2021; Hjorteset & Böcker, 2020; Wang et al., 2021). However, while the number of car sharers is growing, these particular car sharers' characteristics remain being identified in most studies (Amirnazmiafshar & Diana, 2022). This raises the question whether the car sharer characteristics are changing and whether different types of users are being attracted to car sharing. Besides socio-demographic and spatial characteristics, certain personal attitudes are found to impact the intention to use car sharing, such as environmental concerns. The impact of those attitudes varies among studies as, for example, some find environmental concerns to have a positive effect while others find no significant or even a negative effect (Aguilera-García et al., 2022; Becker et al., 2017; Guglielmetti Mugion et al., 2019; Hjorteset & Böcker, 2020; Ramos et al., 2020).

Although studies on the intention to use car sharing provide insight into how factors might be related to its use, they do not investigate the influence of these factors on car sharing use among actual users. Other studies did consider actual car sharing users and the factors that influence their car sharing use. These studies show that while some factors have a similar influence as on the intention to use car sharing services, other factors have a different influence on actual car sharing use. For example, it was found that mainly young people, more often

male and residing in dense urban areas, use car sharing services (Aguilera-García et al., 2022; Burkhardt & Millard-Ball, 2006). However, factors such as income or socio-psychological aspects such as environmental concerns, have a significantly different influence on car sharing use (Aguilera-García et al., 2022; Mattia et al., 2019; Ramos & Bergstad, 2021). In addition, only few studies have considered the influence of different motives on car sharing use. For instance, Mavlutova et al. (2021) found economic and utility-related motives to be the most important for using car sharing services. However, their analyses did not consider possible differences among users and the relationship with the intensity of car sharing use. Ramos et al. (2020) adopted a more comprehensive approach by including socio-psychological aspects and several socio-demographic characteristics to identify different car sharing groups. These groups mainly distinguished themselves on their private car use habits and environmental attitudes. However, the analysis did not consider possible differences between different types of car sharing included in the study.

Besides factors influencing the use of car sharing services, these studies often include the impact of car sharing use on individual travel behaviour to assess the implications of car sharing use on sustainability. Regarding the influence of car sharing use on travel behaviour, it is noticeable that studies on car sharing trip purposes or the modal shift caused by car sharing often neglect variations caused by differences in car sharing use (Becker et al., 2017; Ceccato & Diana, 2021; Papu Carrone et al., 2020). Neglecting the influence of variations in car sharing use might lead to wrong conclusions regarding the total impact of car sharing use.

Reviewing the mentioned studies, it can be concluded that much research on car sharing has been done. However, besides the lack of general consensus on how different factors influence the intention to use car sharing and the actual use of car sharing services, almost all studies treat car sharing users as a homogeneous group. Moreover, very few studies have adopted a comprehensive approach towards usage in which socio-demographic characteristics, spatial characteristics and socio-psychological aspects are included. Therefore, specific knowledge is missing on how car sharers might have different motives to use car sharing services, how these differences might relate to variations in car sharing usage or related impacts and which other socio-demographic or spatial variables might explain these differences. This lack of knowledge makes it challenging for car sharing companies, but especially governmental institutions, to develop effective strategies to stimulate sustainable transportation through car sharing use.

Apart from the discussed knowledge gap concerning potential variations among car sharers, a question remains regarding the growing car sharing population. It stays unclear whether this growth leads to a shift in the demographic composition of car sharers and whether a broader range of individuals are attracted to car sharing. Therefore, examining whether more diverse population segments are attracted to car sharing is crucial, as it can provide insights into the potential expansion of car sharing beyond its traditional niche.

Lastly, neglecting the influence of variations in car sharing use on car sharers trip purpose or the modal substitution of shared cars might lead to incorrect conclusions regarding the impact of car sharing on travel behaviour and sustainable transportation.

1.3. Research objectives and research questions

The main objective of this study is to examine whether different user profiles can be distinguished among car sharers while adopting a holistic approach towards car sharing usage. This approach entails not only including socio-demographic characteristics but also socio-psychological aspects and spatial characteristics. In this way, this study intends to gain a more comprehensive understanding of car sharing use. Furthermore, it intends to identify consistencies and variations among the different user groups and to examine to what extent these can be related to differences in car sharing use. These consistencies and variations between different user groups will provide helpful guidance for car sharing companies and governmental institutions to create specific strategies to stimulate car sharing usage. Eventually, the increase in car sharing usage could help cities become more liveable, better accessible and more sustainable due to the positive impacts associated with car sharing.

Besides this main objective, this study intends to compare how factors such as socio- demographic characteristics and socio-psychological aspects of actual car sharers might differ from those attributed to the typical adopters identified in the literature. In this way, discrepancies between the factors related to the intention or adoption of car sharing and those related to actual users might be identified. These novel insights might suggest that different strategies suit the attraction of new car sharers and the stimulation of car sharing use among current users. This study also aims to examine whether new car sharing users differ from long-term car sharers, as this may indicate whether diffusion of car sharing services in the Netherlands is occurring. Lastly, this work intends to explore relations between car sharing use and the travel behaviour of its users. Therefore, it will consider the influence of usage on the car sharing trip purposes and the modal shift caused by car sharing trips.

To address the research problem and the objectives of this study, the following main research question will be answered:

Which different car sharing user profiles can be identified among car sharers in the Netherlands considering a comprehensive approach towards car sharing usage, and how do these user profiles impact sustainable and equitable transportation?

To be able to answer the main research question, the following sub-questions are formulated:

1. *Which socio-demographic, spatial and psychological factors influence car sharing usage and how can the relations between those factors be conceptualised based upon scientific literature and knowledge?*
2. *How do the characteristics of new car sharers differ from long-time car sharers, and what does this tell about the potential of the car sharing population?*
3. *What is the relationship between car sharing usage and the purpose of trips taken with shared cars, as well as the extent to which shared cars substitute for other modes of transportation?*
4. *To what extent can distinct station-based car sharing user groups be identified upon the identified factors influencing use and the actual usage?*

1.4. Methodology

To answer the formulated research questions, appropriate methods need to be selected. The main method adopted for this research is a Latent Class Cluster Analysis (LCCA) based on survey data of station-based car sharers in the Netherlands. The methodology used to answer all the formulated research questions will be discussed in this section.

The first research question was answered by conducting a literature review. Through this literature review, factors that are known to influence car sharing usage were identified, which resulted in an overview of those factors in a causal diagram. By systematically assessing all factors and reviewing their potential impact on car sharing usage, the basis was formed for the creation of a conceptual model. That conceptual model is based on the identified factors influencing car sharing use and existing behavioural theories. Such existing behavioural theories are, for example, the Theory of Planned Behaviour, the Diffusion of Innovations Theory or the Unified Theory of Acceptance and Use of Technology (UTAUT) (Ajzen, 1991; Rogers, 2003; Venkatesh et al., 2003). These theories include social and personal factors to predict behaviour and have been used before in travel behaviour and car sharing related studies (Mattia et al., 2019; van 't Veer et al., 2023). The final conceptual model captured the relevant socio-demographic characteristics, spatial characteristics and socio-psychological aspects of which it is desired and possible to study the influence on car sharing usage.

To gather data to answer the remaining research questions, a survey was be distributed among members of the station-based car sharing company Greenwheels. The respondents were asked different questions to measure the variables included in the conceptual model. Therefore the survey includes questions about their agreement with specific motives to use car sharing services, various socio-demographic and spatial characteristics. Furthermore questions were asked about the respondents' car ownership and the effect car sharing has had on their car ownership. To measure respondents' actual car sharing usage, customer data on the number of reservations, kilometres driven in the past 12 months, and the membership length were combined with survey data.

The descriptive data obtained from the survey was utilised to answer the second and third research questions. The second research question was answered by reviewing differences in the socio-demographic characteristics of new and long-term car sharers. Through this analysis, insights were gained on how these users compare to the user groups identified by Rogers (2003) in his theory about the diffusion of innovations. These insights may provide additional context regarding the potential growth of car sharing users in general. The third research question was answered by analysing the distribution of car sharing trip purposes for different car sharing usage frequencies and the substitution effect of car sharing for different use frequencies.

To answer the fourth research question, a Latent Class Cluster Analysis (LCCA) was performed. With a LCCA, different groups of station-based car sharing users can be identified based on their shared characteristics (Kroesen, 2021a). In this study, these characteristics are the factors included in the established conceptual model. The identified clusters of the LCCA provide behavioural insights by uncovering underlying structures and patterns of the included factors within each cluster. The context that the clusters provide for the behaviour associated with each cluster makes a LCCA a suitable method to explain how different factors influence car shar-

ing usage. Furthermore, from a theoretical point of view, LCCA is considered an appropriate method for this research since it has multiple advantages over traditional clustering methods. First of all, as LCCA is a probabilistic clustering method, the individuals are assigned to different clusters with a certain probability of belonging to that cluster (Kroesen, 2021a). This differs from deterministic clustering methods where individuals are assigned to a cluster with a probability of one, which may lead to bias in the cluster centres (Magidson & Vermunt, 2002). Furthermore, LCCA can handle variables of different scales (nominal, ordinal, continuous and count), and there are statistical criteria available to determine the optimal number of classes (Magidson & Vermunt, 2002). For the LCCA, the software package LatentGOLD® 5.1 was be used. To prepare the survey data for analysis in LatentGold, IBM SPSS Statistics software was be used.

1.5. Scope

This research was conducted in the Netherlands and considers users of the station-based car sharing provider Greenwheels. The choice was made to focus on Business-to-Consumer (B2C) sharing and, thus, not to consider Peer-to-peer (P2P) and Business-to-Business (B2B) car sharing. The reason to not consider P2P car sharing was that P2P car sharing is generally used for special or specific occasions, whereas B2C car sharing is more often used in people's normal routines (Münzel et al., 2019; Zijlstra, Witte, et al., 2022). Furthermore, with P2P car sharing, the owner of the car determines when the car is available or not, which makes it a much less trustworthy alternative. Therefore, B2C car sharing is considered to be more likely to be a full-fledged alternative to a private car. B2B car sharing was not considered due to the fact that the decision to use a shared car for business-related trips is not made by the individual itself but rather by the individual's employer.

The group of car sharers targeted for the survey were members of the station-based car sharing provider Greenwheels who had used car sharing services at least twice and had their last ride less than six months ago. In this way, it was ensured that the participants were familiar with the car sharing concept and could be considered active members. There were no limitations on the location of members targeted for the survey, allowing participants from all regions of the Netherlands to take part. However, the distribution of shared cars across the country will inevitably effect the geographic makeup of the survey participants.

Furthermore, this study employed a Latent Class Cluster Analysis (LCCA) to identify distinct user profiles among station-based car sharers. Rather than estimating direct influences on car-sharing usage, this approach should reveal the distribution of various variables within the identified clusters. These distributions should provide insights into the expected user groups based on individuals' characteristics and may reveal relationships between different factors.

1.6. Outline of the report

In figure 1.1, a graphical representation of the structure of this report is shown. The first chapter provides context by introducing the research topic and addressing the research problem and knowledge gaps that lead to the formulation of the research questions.

The second chapter describes the theoretical basis of this study and consists of a literature review that aims at identifying the factors that influence car sharing usage and relevant beh-

avioural theories. Eventually, a conceptual model was created shows how the different user groups will be identified.

Next, the third chapter discusses the methods used to answer the second research question. An explanation of the latent class cluster analysis and the operationalisation of the conceptual model is given. In addition, a brief explanation of the preparation of the data is given.

The fourth chapter consists of the data analysis and the application of the latent class cluster analysis. The results of the analysis are discussed. With these results, the remaining research questions are answered.

The fifth chapter provides a comprehensive discussion of the results and compares them to existing literature discussed in the second chapter.

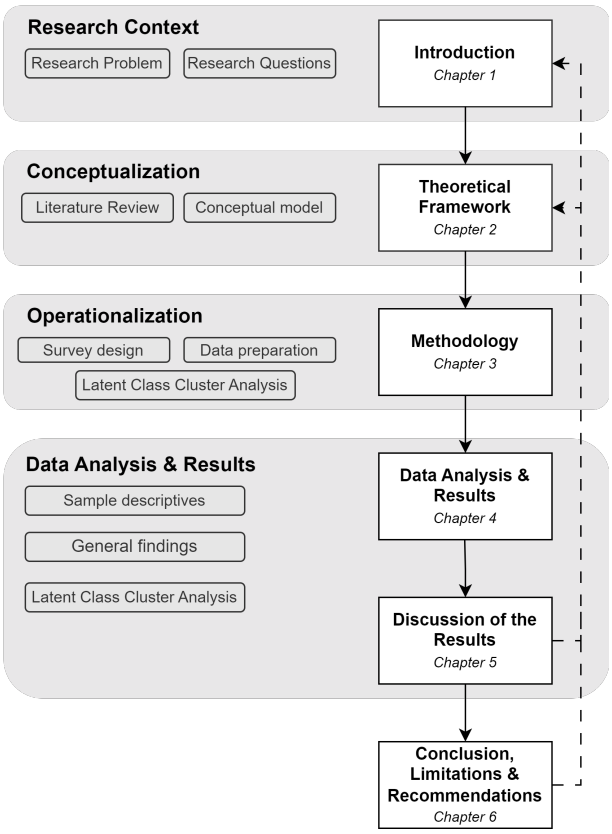

Figure 1.1: Research Design

In chapter six, the main research question is answered. Furthermore, the limitations of the study are discussed, and some scientific and practical recommendations following this study are given.

This thesis was also written in the form of an academic paper, which can be found in Appendix A.

2
Theoretical Framework

This chapter aims to establish a theoretical foundation that enables a comprehensive understanding of how car sharing usage is influenced. To achieve this, the chapter will start by describing the car sharing system characteristics and the current status of car sharing in the Netherlands sections 2.1 and 2.2. Subsequently, a literature review on car sharing will be conducted, presented in section 2.3. The purpose of this literature review is twofold. Firstly, it aims to shed light on the various impacts associated with car sharing. Secondly, and more importantly for this thesis, it aims to explore the factors that influence car sharing usage and examine how these factors influence car sharing usage. Following the literature review, the final section of this chapter presents the conceptual model for car sharing usage. This conceptual model will serve as the foundation for the subsequent chapters of this thesis.

2.1. Car sharing system characteristics

While car sharing has received increased attention in recent years, car sharing programs have permanently been around since the 1990s (Ferrero et al., 2018). The main idea behind car sharing is that a car is not privately owned but shared with others. However, the way cars are shared varies. Figure 2.1 gives an overview of the car sharing systems currently available in the Netherlands. As can be seen, car sharing can be split up into three categories: Business-2-Consumer (B2C), where companies maintain a car fleet that individuals can access, Peer-2-Peer (P2P), where individuals share their private vehicles with others, and Business-2-Business (B2B), where an employer offers shared cars to their employees for business trips.

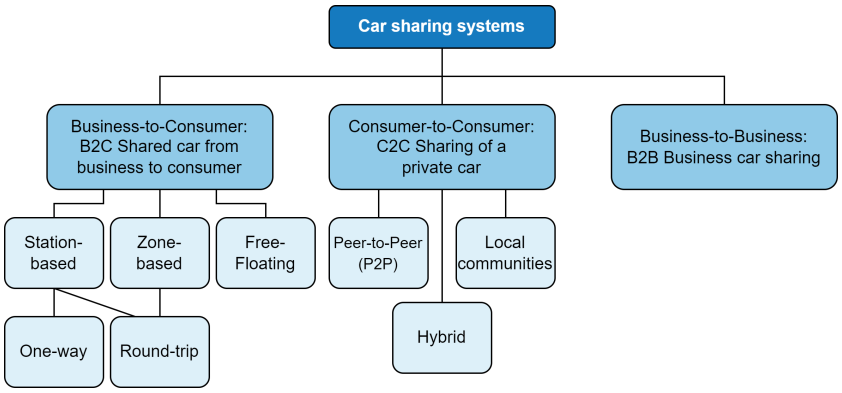

Figure 2.1: Car sharing systems in the Netherlands (Jorritsma et al., 2021, adjusted)

Business-to-Consumer car sharing

Within B2C car sharing, three different operational schemes can be distinguished. First, station-based car sharing is a form of car sharing in which the car has a designated parking spot. In

round-trip station-based car sharing, users are required to return the car to the exact location where it was picked up. As the shared car has a dedicated parking spot, users have certainty about parking spot availability and do not need to search for a free parking spot in the neighbourhood. Alternatively, with one-way station-based car sharing, users can leave the car at a different, but still designated, location. In this way, one-way station-based car sharing offers more flexibility and increases the potential use cases. For instance, the shared car could be used as a first- or last-mile transportation alternative. Another type of round-trip car sharing is zone-based, in which users have to return the car to the same neighbourhood, but the car does not have a reserved parking spot. This type of car sharing requires the user to search for a parking spot but makes more efficient use of available parking spots. Finally, free-floating car sharing is the third form of B2C car sharing, where the shared car does not have to be returned to a designated parking spot but can be parked anywhere within a specific service area. As such, free-floating car sharing provides more flexibility to its users, with the prerequisite that a car is always nearby and available.

Consumer-to-Consumer car sharing

As for B2C, C2C car sharing also has different forms. The most well-known type of C2C car sharing is Peer-to-Peer (P2P), where individuals share their private car with others via an online platform. Alternatively, there are local communities where individuals, often people from the same neighbourhood, share one or more cars. This type of car sharing is sometimes referred to as community-based car sharing and often benefits from increased social control over the use and maintenance of the shared car. Lastly, hybrid car sharing refers to car sharing where multiple individuals have partial ownership of a car that they share between them. The car is owned by a third company but solely used by the group of individuals who partially own it. This type of car sharing is sometimes referred to as fractional ownership.

Business-to-Business car sharing

In B2B car sharing, an employer offers the possibility to its employees to use shared cars for business purposes. The company can own these cars or provide them through a third party. Since B2B car sharing is a closed form of car sharing that is not accessible for people who do not work at a company that offers B2B car sharing, little is known about the impacts of B2B car sharing.

2.2. Car sharing in the Netherlands

This section will discuss the current state of car sharing in the Netherlands, including the number of shared cars and the services available. Figure 2.1, discussed in the previous section, gives an overview of the sharing systems available in the Netherlands.

Figure 2.2 shows the development of the number of shared cars per type in the Netherlands. In 2022, the Netherlands counted 99.000 shared cars (CROW, 2023). The largest share of these shared cars, approximately 75.000, were P2P shared cars offered via online platforms. It should be noted that this was the total amount of P2P shared cars if they were all made available by their owners. Of the remaining 24.000 shared cars, 15.500 were used for business car sharing, and around 2.000 were shared within local communities. The remaining 6.500 were B2C shared cars, accessible to everyone and available 24/7. To put these numbers into perspective, at the end of 2022, the Netherlands counted 8.9 million passenger cars, meaning shared cars represent only 0.0007% of the total number of cars in the country.

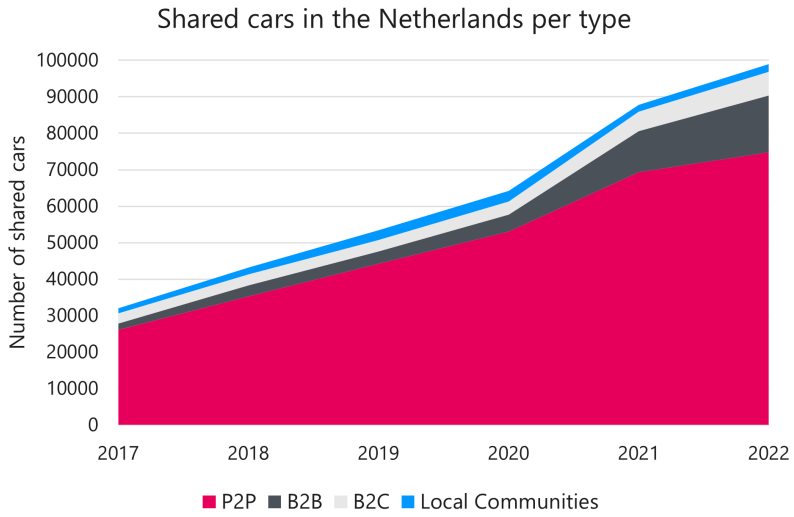

Figure 2.2: Shared cars in the Netherlands per type (CROW, 2023)

The spatial coverage of these shared cars differs across the country, and this can be illustrated by reviewing the number of shared cars for different degrees of urbanisation in the Netherlands. Figure 2.3, presents the distribution of shared cars per type for five degrees of urbanisation. The data of Figure 2.3 is from 2021 and may differ slightly compared to the current situation. However, from the year 2021, it can be seen that, in general, all the considered types of car sharing are predominantly present in very highly urbanised areas. This is particularly true for free-floating car sharing, which is solely present in very highly urbanised areas. For the other types of car sharing, the distribution over the different degrees of urbanisation is broadly similar, with a decline in the number of shared cars as the degree of urbanisation decreases.

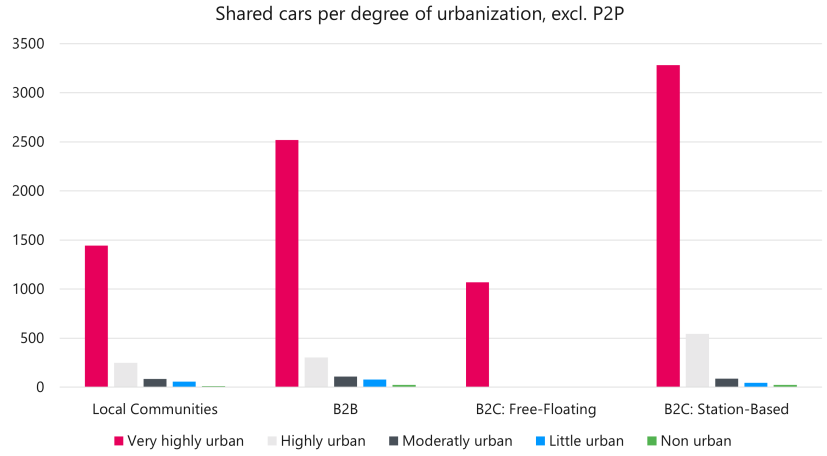

Figure 2.3: Amount of shared cars per degree of urbanisation, excluding P2P (CROW, 2023)

Within the Netherlands, many companies provide car sharing services, varying on aspects such as fleet size, service area and type of service they provide. Table 2.1 provides an overview of the current car sharing providers in the Netherlands, categorised per type of car sharing they offer. As can be seen in Table 2.1, most car sharing companies offer station-based round-trip services. While some of these companies, such as Greenwheels and MyWheels are active in

multiple cities and maintain a large fleet of more than 2000 shared cars, many other companies are only active in one specific area and maintain relatively small fleets of shared cars. Currently, only three companies offer free-floating shared cars, of which two, ShareNow and GreenMobility, are exclusively available in Amsterdam. Only SIXT share operates in multiple cities, thereby offering the possibility to use shared cars for trips between those cities. The car sharing companies that provide local communities with shared cars are rather small and often focused on a specific region.

Table 2.1: Shared car providers in the Netherlands (CROW, 2023)

Station-Based		**Free-Floating**	**Peer-to-Peer**	**Local communities**
Round-trip	*One-way*	ShareNow	SnappCar	Coöperatieauto
Greenwheels	GoSharing	SIXT Share		Deel
MyWheels		GreenMobility		Deelslee
WeDriveSolar				Duurzaam Akkrum-Nes
Ready2Share				Elektrip
Easydriving				HET Deelauto
Axxel				Mobigo
Diks Autodate				Onze Auto
Hely				Schouwen-Duivenland op weg
JustGo				
Kav2Go				
Mobinoord				

2.3. Literature review

This section reviews and discusses the existing literature on car sharing. Specifically, it identifies which factors influence car sharing usage from a user perspective and how each factor influences car sharing usage. Furthermore, it discusses the main impacts associated with car sharing usage. The literature review is structured as follows: First, Figure 2.4 presents a causal diagram which summarises the findings of the literature review. The causal diagram is split up into three different parts: the impacts related to car sharing usage, the intention to use car sharing services and car sharing usage. After explaining the causal diagram, these parts are separately discussed in the following subsections. Moreover, relevant theories on behaviour and technology adoption and usage are discussed in subsection 2.3.5. Useful aspects of these theories are incorporated into the causal diagram and final conceptual model.

2.3.1. Causal diagram of car sharing usage and impacts

Figure 2.4 presents an overview of the findings of this literature review in the form of a causal diagram. It is important to note that the causal diagram only includes factors and causalities considered by the reviewed studies. Therefore, it should not be regarded as an actual representation of car sharing usage and impacts but rather as a summary of the findings in this literature review. This subsection will not discuss every factor included in the causal diagram in detail, as more comprehensive explanations will be provided in the following subsections. Furthermore, in appendix B, an overview of every factor, the influence of that factor and the corresponding reviewed studies can be found.

In the causal diagram, the variables can increase or decrease over time. Moreover, the variables

can cause changes in other variables. These causal relations between variables are represented by a green link, representing a positive relation, or a red link, representing a negative causal relation. Furthermore, grey links are included to indicate a more ambiguous causal relation between two variables. The inclusion of grey links reflects the uncertainty about the influence of a variable arising from varying findings in the literature.

When reviewing the causal diagram, a few remarks can be made, especially when comparing the influence of factors between the intention to use car sharing services and actual car sharing usage. First of all, as substantially fewer studies focused on car sharing usage compared to the intention to use car sharing services, the influence of some factors on car sharing usage has not been studied or found to have a significant influence. Examples of such factors in the causal diagram are household size and residential density, which, therefore, only indicate an influence on the intention. Furthermore, it is interesting to note that there is a discrepancy between the influence of socio-demographic characteristics such as gender, education level, and income on the intention to use car sharing versus the actual usage. These differences are based on the reviewed literature and could indicate that there is a difference between how factors influence the intention to use car sharing services and how they influence actual car sharing usage. However, these differences may also be attributed to the fact that there is substantially less specific literature on how actual car sharing usage is influenced.

Regarding the included socio-psychological factors, it should be noted that the reviewed studies considered a variety of aspects. For example, the social motive was defined differently across some of the reviewed studies, resulting in slightly different estimated relationships for the same socio-psychological factor. However, in the constructed causal diagram, these findings were combined and presented as a single factor. This approach is adopted because most studies aimed to measure the same overarching impact and because it ensured the clarity and comprehensibility of the causal diagram.

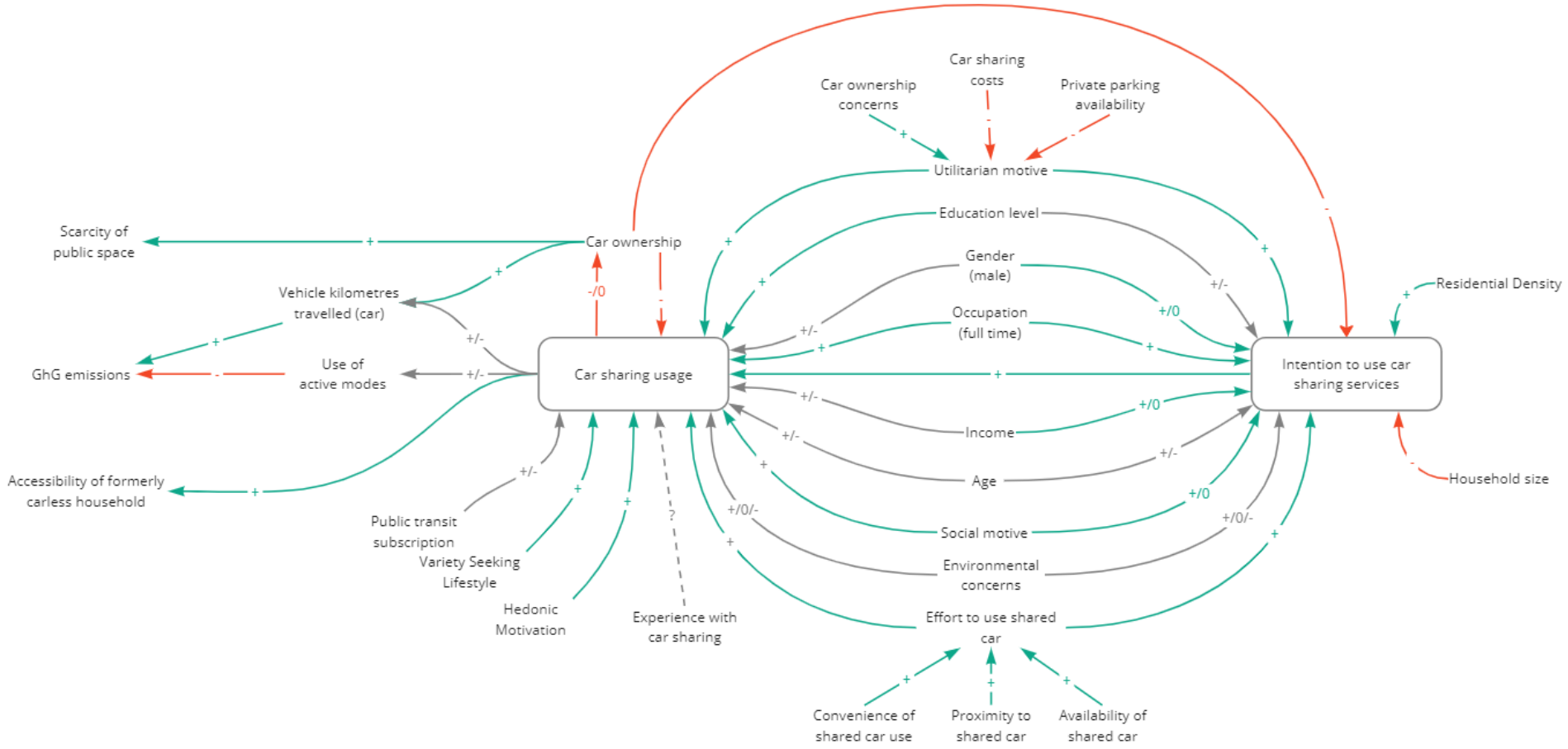

Figure 2.4: Causal diagram of car sharing usage and impacts based upon literature review

2.3.2. Impacts associated with car sharing usage

As stated in the introduction, car sharing is often considered to have various impacts on, among other factors, mobility and sustainability. In this section, literature on the impacts of car sharing is discussed to gain a better understanding of its potential benefits and how car sharing usage influences various aspects. In general, the literature finds that car sharing usage predominantly has an impact on the following factors (Shaheen et al., 2019):

- Car ownership
- Use of alternative (active) transportation modes
- Vehicle Kilometres Travelled (VKT)
- Emission of Greenhouse Gasses (GHG)
- Accessibility of formerly carless households

However, the nature of these impacts is not always evident, and it should be noted that the list of impacts is not exhaustive. Therefore, this section discusses multiple studies on the aforementioned impacts to provide a comprehensive understanding of the impacts associated with car sharing usage.

Car ownership

The impact of car sharing on car ownership has received great interest, especially in recent years. This can be related to the fact that public space is becoming scarce in many dense urban areas and that shared cars might present a possibility to lower the number of parking facilities needed in a neighbourhood (Overheid.nl, 2022). To measure if car ownership decreases when people start using car sharing, questionnaires are often used to ask people if they disposed of a car after they started using car sharing. Moreover, sometimes the hypothetical question of whether people decided not to buy a car due to car sharing is included to measure this 'invisible' effect. Already in 2005, Millard-Ball et al. (2005) reported that in the US, every shared car could replace at least five private vehicles and that it has the potential to replace even more. More recently, Nijland and van Meerkerk (2017) found that car ownership among car sharers in the Netherlands is over 30% lower. They included the invisible effect of not buying a car because of car sharing and found that a shared car mostly replaced a second or third car in the household. Regarding the substitution of private vehicles for shared vehicles, it was found that for the shared car provider Greenwheels in the Netherlands, every shared car replaced 11 private cars (Oldenburger et al., 2019). Similar results were found in Bremen in Germany, where every shared car replaced 15 private cars (Schreier et al., 2018). In addition to this, in a questionnaire on free-floating car sharing in 11 European cities, the study of Jochem et al. (2020) showed that a single free-floating shared car could replace up to 20 private cars in an optimistic scenario. Although the substitution rates vary considerably across the cities they studied, all cities showed a reduction in private car ownership as a result of the availability of free-floating shared cars.

On the contrary, Becker et al. (2018) found that the car ownership reduction for free-floating car sharing was much lower, around 6%. The difference with other studies was that Becker et al. (2018) used a two-wave survey with a control group, one shortly after the start of a car sharing scheme and one a year later, to better assess the actual impact. Even less optimistic results of free-floating car data were found by Kolleck et al. (2021), who determined the substitution rate

empirically by looking at data from 35 German cities. They concluded that free-floating car sharing did not lead to a difference in car ownership. However, for station-based car sharing, results were more positive, as they found that one station-based shared car replaced approximately nine private cars. Reasons for the differences between station-based and free-floating car sharing could be the difference in the reliability of both systems. While free-floating car sharing might be more flexible compared to station-based car sharing, the reliability in terms of availability and proximity might be less. This could be a reason why free-floating shared cars might be considered a less suitable replacement for private cars. Lastly, Bucsky and Juhász (2022), who compared the impact of 129 car sharing systems across Europe on car ownership, found only very minimal effects. They stress that survey-based studies might overestimate the actual effect. However, it should also be noted that not every car sharing system in every considered area was the same and that such a generalisation of the effect on car ownership might not be correct.

It can be concluded that within the scientific debate, no general consensus on the impact of car sharing on car ownership exists. Different systems, such as free-floating or station-based, lead to different substitution rates. Furthermore, other differences in system characteristics and the geographical location of the system might have an influence on the order of magnitude of the effect. However, while there is no consensus on the exact impact, most studies indicate a decrease in car ownership rather than an increase.

Vehicle Kilometres Travelled and GHG emissions

Car sharing can have various impacts on car usage, depending on changes in the travel behaviour of users. The impacts can be caused by car sharing characteristics such as the costs, but also by the reduction of vehicle ownership, which may result in fewer vehicle-kilometres travelled (VKT), less emissions of greenhouse gasses and an increased use of other transportation modes (Shaheen et al., 2019). On the other hand, for people who do not own a car, car usage might increase, and the related impacts may therefore differ. This section will discuss what is known in the literature about the impacts caused by a change in car usage.

First of all, Nijland and van Meerkerk (2017) found that people drive around 15 to 20% less after they start using car sharing. They saw a particular drop in VKT once people had disposed of a private car and concluded that the journeys made by the shared car were most likely to replace train trips or trips with rental cars. The reduction of VKT is supported by studies among users of a specific station-based car sharing provider in the Netherlands, where the average member travelled 1947 kilometres less per year compared to before the membership (Oldenburger et al., 2019). The results of María Arbeláez Vélez et al. (2021), for their study in Amsterdam, also indicated that previous car owners who now use car sharing travel less. However, their results also suggested that people who did not own a car tend to travel more and use less sustainable travel alternatives than before they started using car sharing services. Furthermore, Kopp et al. (2015) compared users of free-floating car sharing services with non car sharers. They found that free-floating users made significantly less car private car trips compared to non car sharers. However, it should be noted that this study solely compared two different groups and did not directly assess the impact of car sharing on car usage.

The emissions of greenhouse gasses (GHG) are primarily associated with changes in travelled car kilometres and the reduced purchase of new cars due to car sharing. A reduction of be-

tween 8 and 13% in CO2 emissions related to decreased car usage and ownership was reported by Nijland and van Meerkerk (2017). As expected due to previous findings on VKT, María Arbeláez Vélez et al. (2021) found that emissions of car-free individuals increased after they started using car sharing while the emissions of car sharers that own a car decreased. However, the impact that car sharing has on the emission of GHG is also influenced by the type of shared vehicle, being either electric or conventional. Additionally, the type of car sharing system plays an important role, with B2C shared cars often being more modern and, therefore, more often fuel-efficient or electric, compared to P2P shared cars, which tend to be older.

Use of alternative (active) transportation modes

Besides the previously mentioned factors, car sharing may also cause a modal shift among its users. In this case, the modal shift refers to a change in travel mode choice caused by the use of shared cars. In a study on the propensity to use car sharing in Italy, Ceccato and Diana (2021) stated that car sharing could substitute car driving trips and would primarily complement public transport. In addition, they found no evidence that car sharing would substitute for biking and walking trips, indicating that car sharing does not negatively influence these active modes. On the contrary, the study of Papu Carrone et al. (2020) concluded that free-floating car sharing would mainly compete with public transport and, to a much lesser degree, private car trips. However, their results were based on survey data from a Danish university which could explain the low substitution of private car trips, as car ownership among university students is usually low.

Different from the previous two studies, Becker et al. (2017) studied actual usage of car sharing. Their results indicated that station-based car sharing reduced car trips and caused an increase in active modes and public transport, while free-floating car sharing caused a shift from public transport and active modes towards the car. However, Becker et al. (2017) also suggested that the usage of free-floating car sharing might be complementary to public transport use, as high public transport trip frequencies were found among free-floating users (Becker et al., 2017).

Accessibility of formerly carless households

Lastly, car sharing is considered to have various social impacts (Shaheen et al., 2019). For households that do not own a car, car sharing could be a way to increase accessibility without having to bear the high ownership costs of a private car. In the Netherlands, it was found that for people who drive less than 10.000 kilometres per year, car sharing is cheaper than owning a private car (CROW-KpVV, 2016). Since Dutch people drive on average 9.000 kilometres per year (CROW-KpVV, 2016), car sharing could be considered an economically beneficial alternative for many people. Additionally, car sharing services are often available 24/7, while public transport is often not. Therefore, car sharing could serve as an additional travel alternative increasing the accessibility for people mostly reliant on public transport services, assuming they have a driving license.

2.3.3. Factors influencing the intention to use car sharing services

The previous section provided more insight into the impacts related to car sharing. The nature of impacts is, among others, dependent on the amount of car sharers. Hence, a substantial amount of research has focused on the potential of car sharing by identifying factors that influence the adoption of car sharing. This section will review those studies and discuss the main

determinants of the intention to use car sharing services. In the causal diagram shown in figure 2.4, the factors influencing the intention to use car sharing services can be seen. A more detailed overview of the related studies to each factor can be found in table B.1 in Appendix B

Studies that focus on the intention to use car sharing mostly use survey data sampled among various populations in the different studies. Some studies were based on surveys set out in specific countries or areas, whereas others targeted specific groups such as university students or residents of densely populated urban areas (Aguilera-García et al., 2022; Circella et al., 2018; Hjorteset & Böcker, 2020; Papu Carrone et al., 2020; Paundra et al., 2017; Wang et al., 2021). Due to the exploratory nature of the studies, the participants of these surveys were mostly non car sharing users, sometimes combined with a small part of actual car sharing users. On top of that, car sharing was not available for all participants in most of the conducted surveys. Aguilera-García et al. (2022) specifically addressed this issue by studying two major European cities where car sharing was available for all survey participants.

Socio-demographic characteristics

The studies on the intention to use car sharing have presented many socio-demographic aspects that influence the adoption of car sharing. The most commonly mentioned and interesting aspects are discussed in this section. First of all, many studies have found that highly educated, young people who are mostly male are most likely to adopt car sharing services (Aguilera-García et al., 2022; Becker et al., 2017; Burghard & Dütschke, 2019; Ceccato & Diana, 2021; Prieto et al., 2017). Besides that, it was found that living in dense urban areas and in households with a low number of cars increases the intention to use car sharing (Aguilera-García et al., 2022; Becker et al., 2017; Burghard & Dütschke, 2019; Ceccato & Diana, 2021; Prieto et al., 2017; Wang et al., 2021). However, for some of the mentioned characteristics, other studies have suggested different impacts. While Münzel et al. (2019) also found that being highly educated and living in a car-free household positively impacted the intention to use car sharing, they found no significant influence of gender and income. In line with this, Hjorteset and Böcker (2020) found no significant effect of gender on car sharing enrolment either. Furthermore, their study suggested that age did not directly impact the adoption of car sharing services. However, this effect was explained through car ownership, meaning that older people were more likely to own a car and, therefore, less likely to adopt car sharing services. Lastly, where almost all studies found the level of education to positively influence the intention to use car sharing, the study of Acheampong and Siiba (2020) conducted in Ghana found a negative influence. A possible explanation might be the positive correlation found between education and car ownership, as car ownership was often found to negatively influence car sharing adoption. This is explained more in the next subsection.

Car ownership

While a change in car ownership is an often-mentioned effect of car sharing, the causality of the relation may also flow in the other direction. This would mean that car ownership influences the intention to use car sharing in the first place. As mentioned in the section on socio-demographic characteristics, multiple studies find that living in a household with fewer cars increases the intention to use car sharing. However, Hjorteset and Böcker (2020) found the relation to be more complex, namely that owning a car seemed to create a greater interest in car sharing in general but that at the same time, owning a car creates a negative impact on actual enrolment in a car sharing membership. In a review of studies that assessed the

influence of vehicle ownership on the adoption of car sharing, Amirnazmiafshar and Diana (2022) stressed the uncertainty about the causality between car ownership and car sharing. Therefore, it remains yet unknown how both factors exactly influence each other and if one is primarily influencing the other if that is not the case.

Parking facilities

Parking facilities and convenience influence the intention to use car sharing in various ways. For example, having a shared car parked within walking distance positively influences the intention to use a shared car (Paundra et al., 2017; Wang et al., 2021). In line with this, Papu Carrone et al. (2020) stressed the importance of available parking facilities for free-floating shared cars, as the value-of-time of individuals when searching for a parking space was found 20% higher than the value-of-time for driving.

Regarding the influence of private parking facilities, Ceccato and Diana (2021) found that the presence of private parking facilities close to someone's home has a strong negative influence on the intention to buy a car sharing subscription. This influence could be explained by the fact that having a car available in front of the house makes people use the car more often (Zijlstra, Witte, et al., 2022). The relation between car ownership and car usage was also studied by Van Acker and Witlox (2010) and confirms that owning a car causes an increase in car use.

Car sharing costs

Regarding the influence of car sharing costs, Wang et al. (2021) found that people were relatively price sensitive, meaning that the attractiveness of car sharing decreased rapidly when costs increased. The high price sensitivity for car sharing was also found by Papu Carrone et al. (2020), who identified that the price sensitivity was also higher compared to other travel modes. Hjorteset and Böcker (2020) supported both studies by distinguishing that people who were regarded to be careful with money tended to have less interest in participating in sharing membership programs. Interesting additions to these findings were those of Paundra et al. (2017), who found that the influence of car sharing costs on the intention to use car sharing differs between people who have different psychological ownership feelings. The results of their study suggested that people with low psychological ownership feelings were more costs-sensitive with respect to car sharing than people with high psychological ownership feelings.

Environmental concerns

A more debated factor is the influence of environmental concerns. Some studies found environmental concerns to have a positive effect on the intention to use car sharing (Guglielmetti Mugion et al., 2019; Hjorteset & Böcker, 2020; Münzel et al., 2019). Whereas others found no significant or even a negative effect (Aguilera-García et al., 2022; Becker et al., 2017; J. Kim et al., 2017). It should be noted here that the type of shared car, electric or conventional, available or presented in the questionnaire might have influenced the relation with environmental concerns. However, all these studies considered the car sharing population as a homogeneous group, which overlooks potential differences between individuals. Addressing this, Ramos et al. (2020) conducted a large European-wide study which identified different mobility styles through hierarchical cluster analysis. While differences regarding environmental concerns were found, it was not possible to determine a clear causal link between environmental concerns and the intention to use car sharing.

Social motives

Besides environmental concerns, other psychological factors, such as social motives or norms, could influence the intention to use car sharing services. These social norms are often defined as the degree to which a person perceives that the use of car sharing is socially desirable. To this extent, Curtale et al. (2021) and Peterson and Simkins (2019) found the social motive to be the most important psychological factor influencing the intention to use car sharing. In the study of Hjorteset and Böcker (2020), the social motive was defined as the degree to which a person can be considered a social person who, for example, is willing to help others and accept help from others. Their results showed no significant influence of the social motive on the intention to use car sharing.

Utilitarian motives

Multiple studies considered the perceived additional utility that car sharing could have for an individual when examining how the intention to use car sharing is determined. For example, Curtale et al. (2021) found a positive influence of car sharing performance expectancy on the intention to use. The performance expectancy, in this case, represented improvements in terms of travel time, modal transfers and engagement in activities at destinations. Similarly, the study of Acheampong and Siiba (2020) showed that motives such as cost saving, more flexibility and less car dependency had a positive influence and were a good predictor of the intention to use car sharing services.

Conclusion on the impact of factors on intention to use car sharing services

From the discussed studies, it became apparent that many have focused on the influence of socio-demographic characteristics. While some studies showed contradictory results, the majority found that factors such as being young, male, and having a higher level of education and income are associated with a higher intention to use car sharing services. Furthermore, factors such as car ownership and residential density are believed to have a relatively clear influence on the use intention of individuals. Lastly, the psychological constructs showed contradictory findings for the influence of environmental concerns. However, the influence of social and utilitarian motives to use car sharing seems to be significantly positive in most of the considered studies. Differences identified by the considered studies might be attributed to the variations in car sharing schemes, population characteristics and how the transportation system of the considered area functions. This shows that while consistencies can be found, results cannot easily be generalised and are not applicable to every potential car sharing case around the world.

2.3.4. Factors influencing actual car sharing usage

The previous section provided an overview of factors which are expected to influence the intention to use car sharing services. As described, these studies are mainly exploratory and are useful to determine whether people are interested in car sharing and what determines their interest. However, whether car sharing can fulfil the potential beneficial impacts as described in section 2.3.2, and to what extent it is able to do so, is dependent on the actual usage. Regarding the actual usage of car sharing, substantially fewer studies have evaluated how the degree of car sharing usage is influenced and in what way certain factors are able to explain car sharing behaviour. This section provides an overview of existing literature on the usage of car sharing and discusses the different findings. A distinction is made between studies that analysed car sharing users and their motives with mainly univariate analysis and studies that explored the

influence of multiple factors on car sharing usage simultaneously.

Again, the findings are summarised in the causal diagram (Figure 2.4). Furthermore, an overview of each factor and studies that examined the influence of that factor can be found in table B.2 in appendix B.

Identifying the car sharing population

Already in 2006, Burkhardt and Millard-Ball (2006) gave a comprehensive review of who car sharers in North America generally speaking are and what their differences with the general population are. The study focuses mainly on describing which demographic sections of the population are attracted to car sharing. Furthermore, since no multivariate analysis was done, the influence of specific factors when controlling for the total set of included factors is not determined. Their most important findings show that car sharers are mainly highly educated people from rather small households with a middle to high income. Furthermore, in the conducted internet survey, they asked respondents about their attitudes towards a variety of statements. By combining the responses on the different statements with the demographic characteristics of those respondents, Burkhardt and Millard-Ball (2006) identified five typical personalities of car sharers: the social activist, environmental protectors, innovators, economizer and practical travellers.

Schaefers (2013) extended this research by identifying four motivational patterns for the usage of car sharing. Conducting a series of interviews with US car sharers, he identified the following motivational patterns: value-seeking, convenience, lifestyle and environment. These motivations are largely in line with the user groups found by Burkhardt and Millard-Ball (2006).

Furthermore, Millard-Ball et al. (2005) studied where and how car sharing succeeds in North America. In line with more recent studies on the intention to use car sharing, they found that car sharers usually live in high-density urban areas with good public transportation travel options available to them. Moreover, they found that a pedestrian-friendly building environment, mixed land use and parking pressure can have a positive impact on car sharing usage. However, similar to Burkhardt and Millard-Ball (2006), the study of Millard-Ball et al. (2005) did not conduct multivariate analysis and therefore did not examine possible relations between included variables.

To that extent, the above-mentioned studies provide insights into who car sharers are and what their possible motivational patterns to use car sharing are. However, to what extent the socio-demographics, spatial characteristics and underlying motivational patterns, relative to each other, are able to explain car sharing usage remains unknown. Besides, these studies were conducted more than ten years ago, while the world and car sharing with it have changed a lot since.

One such change is the introduction of free-floating car sharing, which has gained much attention recently. Since free-floating car sharing offers a different way to use car sharing, the users and their travel behaviour may be different compared to station-based car sharing users. Becker et al. (2017) attempted to answer this question by comparing users of both free-floating and station-based car sharing services in Switzerland. Their analysis showed that both systems mainly attract younger, highly educated people living in households with few private cars, which is in consensus with previous studies (Burkhardt & Millard-Ball, 2006; Kopp et

al., 2015). Compared to station-based, free-floating car sharing was found to be used more among young men with higher incomes whose residential location is not optimally served by public transportation (Becker et al., 2017). In contrast to Burkhardt and Millard-Ball (2006) and Schaefers (2013), the influence of environmental concerns on usage remained unclear as almost no differences with non car sharing users were found.

Influence on car sharing usage in multivariate analysis

Over the last couple of years, multiple studies have been conducted that considered the influence of multiple different factors on car sharing use simultaneously. The studies differ in the way they define the dependent variables that represent car sharing usage. D. Kim, Ko, and Park (2015) and Mattia, Guglielmetti Mugion, and Principato (2019) considered the intention to continue and to re-use car sharing services. Münzel et al. (2019) estimated a model to predict high usage frequency among car sharers as a binary variable, and lastly, Aguilera-García et al. (2022) and Becker et al. (2017) both considered the frequency of car sharing use as the dependent variable. In addition, Ramos et al. (2020) tried to identify different user and non-user mobility styles based on various aspects, including socio-psychological ones.

First of all, Mattia et al. (2019) studied the intention to re-use free-floating car sharing services in Italy through the theory of planned behaviour. Their study focused on the constructs included in the Theory of Planned Behaviour that were expected to influence the usage of free-floating car sharing and purposely added environmental aspects. They concluded that environmental concerns influenced the intention to re-use free-floating car sharing less than other, more utilitarian motives. Besides, they also concluded that the costs were still perceived as too high by users and formed a barrier to using the service more often. D. Kim et al. (2015) studied the intention to continue to use electric vehicle sharing programs in Seoul, South-Korea, by estimating an ordered probit model. The included socio-demographic characteristics showed some interesting impacts that differ from other studies. For example, it was found that females were more likely to continue to use electric vehicle-sharing programs. Furthermore, older people and people with lower incomes were found to be more likely to continue to use the services. These results oppose the findings of previously discussed studies that identified young people, who are mostly men and have high incomes, as typical car sharers. A possible explanation for the contradictory findings of D. Kim et al. (2015) may be the survey sample, which targeted car sharers with a strong inclination to change their travel modes rather than the general population.

Instead of studying the intention to re-use car sharing services, Münzel et al. (2019) conducted a logistic regression analysis to estimate the influence of different factors on highly frequent car sharing use. In addition to socio-demographic characteristics, the analysis incorporated several attitudes and motivations to use car sharing services. However, aside from education level and having a public transport subscription, no other variables were found to have a significant influence on the frequency of car sharing use. Contradictory to these findings, Becker et al. (2017) found that having a public transport subscription had a negative influence on the frequency of use for both free-floating and station-based car sharing services. Furthermore, they found that living in a car-free household positively influenced the frequency of use for both types of car sharing, and that being male only had a significant positive impact on free-floating services. The study of Becker et al. (2017), however, did not include socio-psychological factors such as attitudes or motivations.

The study of Aguilera-García et al. (2022) on the frequency of use for FFCS in Madrid and Munich, however, did include several attitudes related to car sharing. Of the included attitudes, having a variety-seeking lifestyle (VSL) had the most influence on the frequency of use. Regarding environmental concerns, different than Mattia et al. (2019), Aguilera-García et al. (2022) found that these concerns had a negative influence on the frequency of use in both cities. This is particularly interesting for Madrid, as all free-floating shared cars were either fully electric or hybrid. Regarding the effect of demographic-related factors, the results showed little similarities between both cities (Aguilera-García et al., 2022). In Munich, women showed a lower frequency of use, while in Madrid, this effect was explained by the two latent constructs VSL and the intrinsic preference for driving. Furthermore, the influence of income differed; in Madrid, middle incomes showed a higher use frequency compared to low and high incomes, while in Munich, the frequency of use increased as income increased.
Ramos et al. (2020) adopted a different approach to explore what determines the use of car sharing services. Their study aimed to identify different mobility styles of car sharers and non car sharers by, among others, including socio-psychological attitudes. Through hierarchical clustering they identified three different car sharer types. The attitudes of the three groups differed primarily on their environmental motives and utility-related motives for car sharing use. Furthermore, the habit of using a car differed significantly between the identified groups. In addition to this study, Mavlutova et al. (2021) explored several motives for using car sharing services. They identified that car sharing motives could usually be divided into three categories: environmental benefits, economic-benefits and utitlity-related aspects, which in their case also included the perceived effort to use the service. The results of their study suggested that economic motives, together with utility-related motives, are the most important. However, their study only used aggregate results and did not account for individual variations regarding the motives.

Conclusion on factors influencing car sharing usage from a user perspective

All in all, it can be concluded that many studies have described car sharing users using descriptive data, such as socio-demographics. Although differences exist, such as variations between different types of car sharing, the literature generally indicates that car sharers are predominantly younger individuals with an average or above-average income. Moreover, they tend to reside in small households with little private cars available. However, when examining the impact of different factors on actual car sharing usage in multivariate analyses, the results are less evident. For instance, the significance of socio-demographic characteristics varies widely among the discussed studies. A possible explanation for these differences is the variety of included characteristics in each of the studies. Since not every studies included the same set of variables in its analysis, correlations between variables may differ, which could have an influence on the significance of those variables with respect to their impact on the amount of car sharing usage. Another possible explanation for the differences observed between the studies could be the differences in sample populations caused by the different study areas. For instance, car sharing usage may be influenced by different socio-demographic characteristics across different populations, or the impact of these characteristics may vary. This is exemplified by the research of D. Kim et al. (2015) related to the use of electric car sharing in South-Korea, which illustrated the different findings on the influence of socio-demographic characteristics compared to similar studies conducted in Europe.

Moreover, the influence of psychological constructs seems to differ between the few studies

that did include these constructs. It is important to take into account where the differences between studies originate from since the results may not be applicable to every car sharing case. As mentioned for the varying socio-demographic results, such differences could originate from different study approaches. However, as discussed, the study by Aguilera-García et al. (2022) demonstrated that even when the type of car sharing system is the same, specifically free-floating, the factors influencing usage frequency can vary significantly between two different cities in two different countries. This emphasises that besides the type of car sharing, contextual factors which vary between countries and cities indeed have an important influence on the usage of car sharing services. From the little studies that also included motives to use car sharing services, it appears economic- and utility-related motives are important. However, as only the study Ramos et al. (2020) considered possible differences among users, more research is needed to explore what different car sharing user profiles exist.

2.3.5. Theories on behaviour and technology adoption and usage

This section discusses a selection of existing theories on behaviour and technology adoption and usage. These theories provide additional information and context on how the behaviour of individuals is influenced and what determines the usage of (novel) technologies or systems such as car sharing. A brief explanation of each theory will be given, and the applicability of the theory with respect to car sharing usage will be discussed. Relevant aspects of the theories are included in the causal diagram in Figure 2.4.

Theory of Planned Behaviour

The first theory included is the Theory of Planned Behaviour (TPB). The TPB is a theory developed by Ajzen (1991) and is an extension of the earlier developed Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980). The TPB states that an individual's intention to show certain behaviour can directly be related to the actual behaviour of an individual. This behavioural intention to perform certain behaviours is moderated by three different aspects: (I) attitudes, (II) subjective norms and (III) perceived behavioural control (Figure 2.5). The attitudes represent how someone evaluates the behaviour, as either being favourable or unfavourable behaviour. Subjective norms are the perceived influence of social norms on the desirability to perform or not perform the behaviour. Lastly, perceived behavioural control means one's perception of whether he or she is in control of his or her own behaviour. According to Azjen and Fishbein (2005), these three aspects are influenced by an individual's beliefs about oneself and are determined by a variety of background factors.

Regarding the applicability of the TPB to study car sharing usage behaviour, Mattia et al. (2019) has shown that an adjusted version of the TPB indeed can be used to assess the intention to reuse car sharing services. Moreover, within the travel behaviour domain, the TPB has widely been applied before, for instance, to determine individuals' commuter mode choice (Donald, Cooper, & Conchie, 2014). As such, the TPB could be considered an appropriate conceptualisation to evaluate car sharing user behaviour. However, it should also be noted that the TPB has received criticism on the fact that it does not include the influence of a person's previous behaviour (Sommer, 2011). When examining the factors that influence car sharing usage among car sharers, it might be important to consider the influence of previous behaviour.

In the causal diagram shown in Figure 2.4, attitudes such as environmental concerns and utilitarian motives can be seen. Furthermore, the subjective norm is included as a social motive to

use car sharing services. Lastly, perceived behavioural control is also included. As discussed in sections 2.3.3 and 2.3.4, these factors were found to significantly influence car sharing intention and usage in multiple studies.

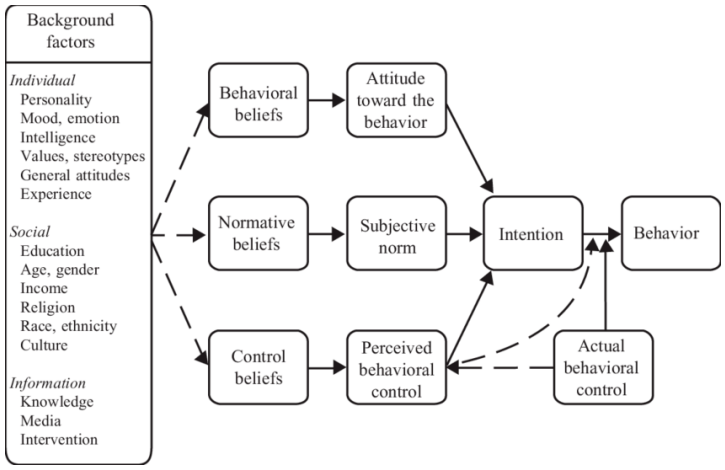

Figure 2.5: Theory of Planned behaviour (Azjen & Fishbein, 2005)

Technology Acceptance Model

The Technology Acceptance Model (TAM) was first created by Davis (1989) and states that the actual use of a technology or system is influenced by the perceived usefulness and the perceived ease of use of that technology (see figure 2.6). The perceived usefulness, in this case, means to what extent a person believes that the use of a system or technology would be beneficial for him or her. The ease of use refers to whether a person believes that the use of the system or technology would be effortless or not. Both aspects can be influenced by external variables such as system characteristics, prior knowledge and social influences (Venkatesh & Davis, 1996).

One of the most commonly mentioned advantages of the TAM is its relative simplicity since it assumes that only two factors, perceived usefulness and perceived ease of use, influence behavioural intention. However, this simplicity is also a point of criticism. For example, the fact that the TAM excludes the influence of others on an individual's behavioural intention (Ajibade, 2018; Straub, 2009).

Within car sharing research, Buschmann et al. (2020) used a combination of the TAM and the theory of reason action to predict the intention to adopt electric car sharing services in Taiwan. Their study indicated that from a theoretical point of view, the proposed model was valid. From a practical perspective, the results showed that personal attitudes were the most important factor when predicting the intention to adopt electric car sharing services. Furthermore, the perceived usefulness had a small, but significant influence on the intention and was found to be highly influenced by the perceived ease of use.

The applicability of the TAM model with respect to car sharing usage lies in the fact that the TAM stresses the importance of the perceived system characteristics. For example, the perceived usefulness of car sharing can be considered a very relevant aspect. When car sharing is not perceived as useful because owning a car which can be parked right in front of someone's

house is perceived as a better alternative, one's intention to use car sharing is likely very low. Similar examples can be made for the perceived ease of use. When there are very few shared cars nearby or using a shared car is very difficult, the intention of people to use car sharing will not be very high. In the causal diagram, aspects related to the perceived usefulness and ease of use can be found influencing the utilitarian motive to use car sharing services and the perceived behavioural control.

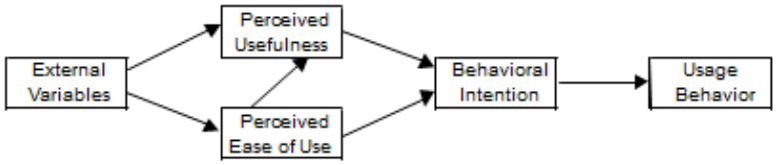

Figure 2.6: Technology Acceptance Model (Venkatesh & Davis, 1996)

Diffusion of Innovation theory

Another theory related to the adoption process is the Diffusion of Innovation (DOI), which explains the adoption of an innovation over time through the population (Rogers, 2003). According to Rogers (2003), the adoption of an innovation is a gradual process in which different segments of the population adopt an innovation at different times. Figure 2.7 visualises this process and shows that some part of the population adopts an innovation rather quickly, such as the innovators and early adopters, and other parts of the population adopt an innovation rather late, such as the laggards. In his theory, Rogers (2003) defines five key elements which influence the diffusion of an innovation: the innovation, the adopters, the communication channels, time and the social system. Besides these key elements, the theory consists of five perceived characteristics of the innovation which influence one's adoption decision. The five perceived characteristics are: (**I**) the perceived *relative advantage* of an innovation compared to the current situation, (**II**) its perceived *compatibility* with the current value's and needs of the user, (**III**) the perceived *complexity* to use the innovation, (**IV**) the *trialability*, whether potential users can test the innovation before the adopt it and, (**V**) the *observability* of the effects of innovation.

The Diffusion of Innovation theory has been applied in many fields of study, as well as to the adoption process of car sharing (Seign & Bogenberger, 2012; Vanheusden, van Dalen, & Mingardo, 2022). Both studies find that the socio-demographic characteristics associated with current car sharing users correspond with the typical characteristics of innovators and early adopters, meaning that for car sharing, the early majority still has to be activated to start using car sharing. While it is not given, and probably not likely, that the whole population will use car sharing, the fact that currently only a very small segment of the population uses car sharing means that its potential beneficial impacts are not yet completely fulfilled. In light of this research, examining whether the characteristics of station-based car sharers in the Netherlands align with those of early adopters could suggest something about its potential. More importantly, by identifying who the users are and what possible user profiles exist among car sharers, attempts could be made to address segments of the population that are not yet attracted to car sharing.

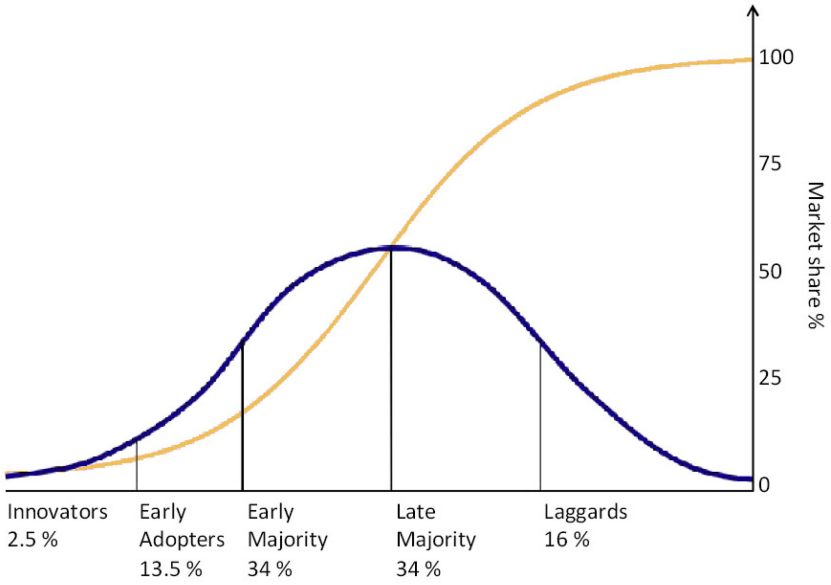

Figure 2.7: Diffusion of Innovation theory (Rogers, 2003)

Unified Theory of Acceptance and Use of Technology

The last theory that will be discussed is the Unified Theory of Acceptance and Use of Technology (UTAUT) which was first developed by Venkatesh, Morris, Davis, and Davis (2003). In their study Venkatesh et al. (2003) reviewed eight theoretical frameworks on the adoption and use of technology, among which the Theory of Planned Behaviour, the Technology Acceptance Model and the Diffusion of Innovations theory, and combined these theories into one unified model. The original UTAUT model includes four factors determining usage, (**I**) *performance expectancy*, which is the extent to which a person believes that the use of the system will be beneficial, (**II**) *Effort expectancy*, which is the perceived ease of use of system, (**III**) *social influence*, which is the extent to which a person perceives that the use of the system is socially desirable and, (**IV**) *facilitating conditions*, which is the extent to which an individual believes that the technical and organizational structure of the system is present to support the use of the system (Venkatesh et al., 2003). These factors are assumed to be moderated by four, and four moderators of use behaviour being (**I**) *age*, (**II**) *gender*, (**III**) *experience* and, (**IV**) *voluntariness of use*.

In 2012 the UTAUT model was updated to the UTAUT2 model (Figure 2.8) so that it focused more on consumer use of technology instead of organisation use (Venkatesh, Thong, Xu, & Walton, 2012) to adapt it to consumer technology context. Venkatesh et al. (2012) added three factors that influence use, (**I**) *hedonic motivation*, which is the perceived joy or pleasure derived from using a certain technology, (**II**) the perceived *price value* of a technology and, (**III**) *habit*, which is the extent to which a person performs automatic behaviour. Furthermore, the voluntariness of use was removed as a moderator in the UTAUT2 model.
Within the travel behaviour research domain, the UTAUT and UTAUT2 models have been applied in multiple studies. For instance, to assess the factors that influence bike sharing acceptance and use (Jahanshahi, Tabibi, & van Wee, 2020), to study the user acceptance of electric car sharing services (Curtale, Liao, & van der Waerden, 2021), or to explore the acceptance of autonomous public transport systems (Korkmaz, Fidanoglu, Ozcelik, & Okumus, 2021). These studies demonstrate that the UTAUT(2) model can be regarded as a suitable model to

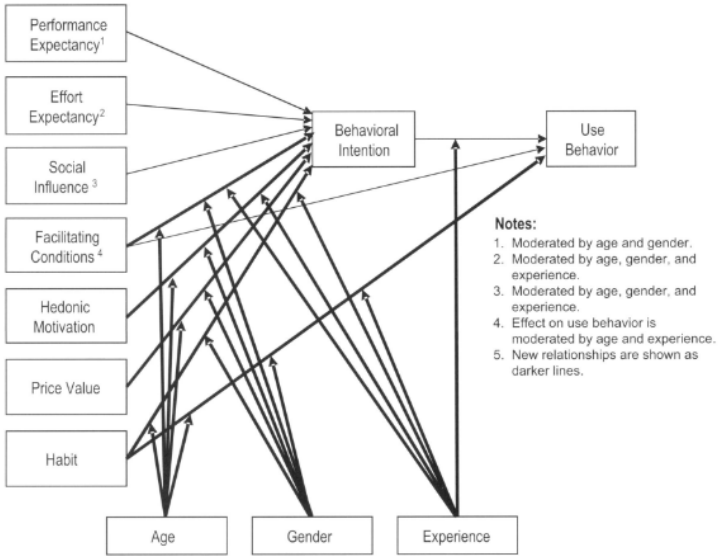

Figure 2.8: UTAUT2 model (Venkatesh et al., 2012)

conceptualise car sharing intention and use. However, the factors that are found to significantly influence behavioural intention vary across studies. In the study of Jahanshahi et al. (2020), the factor *facilitating conditions* was found to be the strongest predictor of behavioural intention. The study of Curtale et al. (2021), however, found the factor *effort expectancy*, which measures a to a certain extent similar effect, to be the weakest predictor of behavioural intention. Instead, they found the factor *social influence* to be the most important predictor of behavioural intention. Lastly, Korkmaz et al. (2021) found *trust and safety* to be the most important predictor. Since their study examined the adoption of autonomous public transport systems, this might have been expected, but it also stresses that contextual factors such as the studied system and area have a great impact on the outcome of these studies.

Multiple aspects included in the UTAUT2 model overlap with aspects mentioned by previously discussed theories and aspects found by other studies reviewed in sections 2.3.3 and 2.3.4. However, some aspects of the UTAUT2 model have been added to the causal diagram (Figure 2.4). The first addition is the influence of experience with car sharing services, and the second addition is the factor of hedonic motivation. Both factors were not included based upon the reviewed studies in sections 2.3.3 and 2.3.4.

2.4. Conceptual model for Latent Class Cluster Analysis

Based on the conducted literature review and constructed causal diagram for car sharing usage, the conceptual model for the subsequent Latent Class Cluster Analysis (LCCA) is established and depicted in Figure 2.9. The reasoning behind including or excluding specific aspects that were identified to influence car sharing use is provided. The operationalisation of the included aspects, i.e. how they are measured, is elucidated in the following chapter. Furthermore, the subsequent chapter comprehensively explains the theory underpinning the Latent Class Cluster model and analysis.

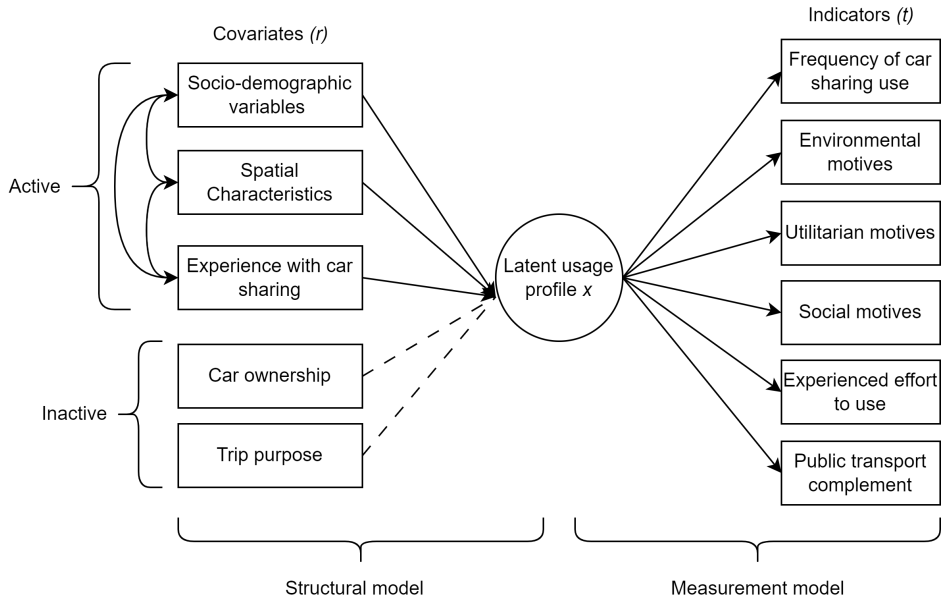

Figure 2.9: Conceptual latent class cluster model

The model shows that different latent usage profiles, which represent the identified user groups, are based on a set of chosen indicators and covariates. For the indicators, individuals' actual car sharing use and their different motives for using car sharing are chosen. The different types of motives are measured through multiple statements, which are elaborated in the next chapter. On the left-hand side of the model, the covariates are displayed. These covariates are assumed to influence belonging to a specific user group. Considering causality, it makes sense to incorporate individuals' motives and car sharing use as indicators. Covariates, such as socio-demographic and spatial characteristics, are assumed to influence the chance of belonging to a specific user group characterised by particular motives and car sharing use. In this way, the model conceptually assumes that personal motivations to use car sharing and the amount of car sharing use are influenced by the covariates and not the other way around.

Regarding the indicators, the most important types of motives for using car sharing identified in the literature are included. These are the utilitarian, environmental and social motives and the experienced effort to use shared cars. The utilitarian motives capture how different perceived benefits motivate car sharing use. The environmental motives capture to what extent car sharing use is motivated by the individuals' belief that car sharing contributes to a better environment. Social motives are included to capture the influence of subjective norms, such as the opinion of others on an individual's choice to use shared cars, and the hedonic motivations to use shared cars, such as experiencing driving as fun or having a preference for sharing goods. The experienced effort to use shared cars is included to capture to what extent individuals feel they need to make an effort to use shared cars and if they are satisfied with the service. In addition to these motives, which are also represented in the causal diagram, the motivation 'complement to public transport' is added to account for the interaction between shared cars and public transport. For instance, shared cars can serve as a last-mile transportation option following a train trip or as an alternative when public transport is insufficient. Lastly, an individual's actual car sharing frequency is included as an indicator.

Compared to the socio-demographic variables identified in the literature, a reduced number is included in the conceptual model. Because it was not desirable to include questions regarding income, gender and occupation in the survey, these characteristics are excluded. The remaining socio-demographic characteristics are age, education level and household size. While household size does not directly influence car sharing usage in the causal diagram, it is included in the conceptual model due to its significant effect on the intention to use car sharing and, consequently, its expected influence on car sharing usage.

Furthermore, two spatial characteristics are included as covariates, which were not directly influencing car sharing usage in the causal diagram due to their absence or significance in studies on actual car sharing use. However, both residential density and the presence of private parking showed significant effects on the intention to use car sharing services. Therefore, both aspects are also included in the conceptual model. More specifically, the term 'parking facilities' is used instead of private parking availability since this work also aims to study the influence of free and paid on-street parking.

Lastly, trip purpose, car ownership and experience with car sharing are included as covariates. Experience with car sharing is included based on its presence in the UTAUT2 model and because its influence on car sharing usage has yet to be studied extensively. Including trip purpose reflects that individuals may vary in their car sharing use and motives for use based on their car sharing travel purposes. In order to avoid endogeneity issues, where a covariate is dependent on the variable it is trying to predict, both car ownership and car sharing trip purpose are included as inactive covariates. This is because both factors may be influenced by indicators such as the frequency of car sharing use or various motivations. Further explanations of the role of inactive covariates can be found in the next chapter.

When comparing the conceptual model to the causal diagram, it becomes clear that the intention to use car sharing services is not included. This is because the study focuses on the actual usage of shared cars and the motives to use them rather than the intention to use them.

3 Methodology

This chapter discusses the methodology employed to analyse the data and address the formulated research questions. Section 3.1 discusses the basic principles of a Latent Class Cluster Analysis (LCCA). Section 3.2 elaborates on the survey design and data gathering process. In section 3.3, the Latent Class Cluster model is discussed. Finally, in section 3.4, the gathered data are prepared for the subsequent analysis, which is presented in chapter 4.

3.1. Latent Class Cluster Analysis

Latent Class Cluster Analysis (LLCA) is a model-based probabilistic clustering method aimed at revealing groups of research units, in this case, station-based car sharers. These groups, also called clusters, are similar based on certain observed characteristics, which are, in this case, the factors included in the conceptual model (Kroesen, 2021a). By identifying different clusters, it is possible to understand certain behaviours better since the different cluster profiles provide context for the behaviour associated with that cluster (Kroesen, 2021a).

The main theoretical idea of LCCA is that an underlying discrete latent class variable accounts for the associations between a set of indicators (Molin et al., 2016). It does so that, conditional on that latent class variable, the associations between those indicators become insignificant (Molin et al., 2016). This is also known as the local independence assumption. In other words, the identified latent classes provide an alternative explanation for the observed correlations between the indicators included in the model. For example, it might be that respondents who are driven by environmental motives are less frequent car sharing users and that respondents with mainly utilitarian motives show higher user frequencies. Different latent clusters representing both user groups could explain these correlations between the motives and the frequency of car sharing use.

The goal of any clustering method is to maximise the homogeneity within the clusters and heterogeneity between the clusters. Unlike traditional deterministic clustering methods, such as K-means clustering, LCCA is a probabilistic clustering method. This means that individuals are assigned to different clusters with a certain probability of belonging to that cluster, rather than deterministic, i.e. with a probability of one, to different clusters (Kroesen, 2021a). This is one of the main advantages of LLCA compared to traditional deterministic clustering methods because it prevents biases in cluster centres due to the deterministic assignment of individuals to the different cluster centres (Magidson & Vermunt, 2002). Other advantages of LCCA are that it can handle variables of different scale types (nominal, ordinal, continuous and count) and that statistical criteria are available to determine the optimal number of classes (Magidson & Vermunt, 2002).

For deterministic clustering methods, such as K-means clustering, the amount of clusters needs to be predetermined by the researcher without the possibility of relying on formal diagnostic statistics (Magidson & Vermunt, 2002). Differently for a LCCA, the optimal amount of clusters, that is, the least amount of clusters which sufficiently explains the correlation between the indicators, can be determined with the help of various statistical criteria (Molin et al., 2016). Commonly used statistical criteria are the likelihood-ratio chi-squared statistic L^2, the Bayesian information criteria (BIC), Akaike's information criterion (AIC) and the Bivariate Residuals (BVR) (Magidson & Vermunt, 2004; Molin et al., 2016). The likelihood-ratio chi-squared statistic assesses to what extent the expected cell frequencies differ from the observed cell frequencies with the null hypothesis that the difference is zero and thus no relationship exists in the population (Magidson & Vermunt, 2004). The null hypothesis is usually rejected if the p-value of the $L^2 > 0.05$, which indicates that the model fits the data well. However, in cases of sparse data, the χ^2 distribution should not be used to determine the p-value for the L^2 because, in this case, the χ^2 statistic will no longer approximate a χ^2 distribution (Magidson & Vermunt, 2004; Molin et al., 2016). The BIC and AIC are both global model fit information criteria based on the likelihood function. Since adding parameters to the model leads to better fitting models by definition, because the maximum likelihood estimation increases, both criteria penalise the addition of parameters. When assessing the BIC and AIC, lower values are preferred for both criteria. Lastly, the BVR is a local model fit criterion which shows the existing association between the indicators in the model. Since the BVR is calculated as the χ^2 divided by the degrees of freedom, a BVR greater than 3.84 indicates a significant residual association at a significance level of 5%. So, in essence, the BVR indicates to what extent the latent class model successfully achieves local independence.

Besides these above-mentioned statistical criteria to determine the optimal number of clusters, some additional aspects can be considered when determining the number of clusters. For example, cluster sizes of at least 5% are usually desired to assure the interpretability of the results (Weller et al., 2020). In general, the theoretical interpretability of the clusters should be taken into account when choosing the number clusters for the model (Weller et al., 2020).

To be able to predict class membership, that is, the probability of an individual belonging to a certain cluster, covariates can be added to a latent class cluster model (Vermunt & Magidson, 2002). These covariates are, for example, socio-demographic characteristics such as age or gender. To determine whether or not to include a covariate in the model, its significance can be tested with the Wald-statistic, which is a chi-square test of which the number of degrees of freedom is equal to the number of constraints (Vermunt & Magidson, 2016). Covariates with a Wald-statistic p-value < 0.05 indicate statistical significance and thus can be included in the model as active covariates. Non-significant covariates, however, can still be included in the model as inactive covariates. Inactive covariates do not influence class membership but can provide information about the distribution of that covariate within a cluster (Molin et al., 2016). For example, this way, one could still observe the distribution of age within the clusters even if the covariate age would be statistically non-significant.

3.2. Data gathering

A survey must be designed to gather the necessary data to perform Latent Class Cluster Analysis (LCCA) and answer the remaining research questions. In this section, the survey design is presented, and the operationalisation of included variables is clarified. The survey questions used for this thesis are part of a survey conducted for customer research of Greenwheels. Therefore, not all survey questions are relevant to this research, and thus, not all questions will be discussed. An overview of all the questions used for this thesis can be found in appendix C. The survey was conducted online and was only available in Dutch.

Measurement of the indicators

To obtain measures for the indicators, the respondents' attitudes on various statements related to socio-psychological aspects in the conceptual model were queried. The statements used to measure the attitudes of respondents were inspired by previous car sharing studies that considered socio-psychological aspects and were adjusted to fit this research. All attitudes of the respondents were measured on a 5-point Likert scale. The included statements were discussed per category but were included separately in the upcoming Latent Class Cluster Analysis. Section 3.3 discusses in more detail why the statements were included separately.

Environmental motives

As discussed in chapter 2, the environmental aspects of car sharing are believed to influence the usage. Respondents were asked about their agreement with three statements to assess the influence of environmental motives on the use of car sharing services; (I) 'For me, a motive to use shared cars is the lower emission related to shared cars compared to private cars'; (II) 'A reason for me to use shared cars is that by doing so I contribute to reduction traffic in my city'; (III) 'I use shared cars because it contributes to creating extra space for other/enjoyable things in my city'. All three questions were answered on a 5-point Likert scale ranging from (1) strongly disagree to (5) strongly disagree. The selected questions originated from questions previously used in other studies and were adjusted to align with station-based car sharing (Aguilera-García et al., 2022; Curtale et al., 2021; Mattia et al., 2019). Furthermore, the questions were transformed from agreeing with a presented fact to a personal motive for using shared cars.

Utilitarian motives

The utilitarian motives aim to identify to what extent car sharing usage is motivated by the added value for the users. To assess the influence of utilitarian motives, participants were asked to what extent they agree with the following three statements: (I) 'I use shared cars because it enables me to save money compared to owning a private car'; (II) 'I use shared cars because it is easier than owning a private car'; (III) 'I use shared cars because it improves the quality of my trip compared to the mode of transport I would have used otherwise' and (IV) 'I use shared cars because it means I do not have to look for a parking place for my car'. The first question was similar to the question asked in the study of Mattia et al. (2019), while the second and third questions were not directly derived from previous studies but were based upon findings in the literature on motives to use car sharing. The second question emphasised the potential convenience of car sharing, which was found to be an important motive (Schaefers, 2013). The third question assessed to what extent shared cars were used because it was seen as an improvement of the travel journey of the respondent. Lastly, the fourth question originated from the fact that one of the advantages of station-based car sharing was the certainty of a

parking spot.

Social motives
The social motives capture multiple, slightly different social aspects of car sharing. They assess to what extent car sharing usage is motivated by the influence of others, the fun derived from driving in a car and one's attitude toward sharing goods. To do so, the participants were asked for their agreement on the following three statements. (I) 'People around me encourage me to use shared cars'; (II) 'I use shared cars because I enjoy driving in a car'; (III) 'I use car sharing services because sharing goods with others appeals to me'. The first statement was taken from the Theory of Planned Behavior of Ajzen (1991), where it was used to measure the subjective norm. The second statement addressed a hedonic part of car sharing and has been used before by Aguilera-García et al. (2022) and J. Kim et al. (2017). However, this statement was adjusted to assess the use of shared cars because of the joy derived from driving instead of someone's general enjoyment of driving. The third statement was inspired by Aguilera-García et al. (2022).

Experienced effort to use car sharing
To determine the participants' experienced effort to use car sharing, they are asked to respond to the following three statements. (I) 'I find it easy to use car sharing services'; (II) 'I am satisfied with the distance from my house to the shared cars I use'; (III) 'Shared cars are not always available when I intend to use them'. For the first statement, respondents need to indicate how easy the use of shared cars is from (1) very difficult to (5) very easy. For the second statement, the possible response ranges from (1) very dissatisfied to (5) very satisfied, and for the last statement, the respondents indicate their agreement from (1) strongly disagree to (5) strongly agree. The statements are inspired by the statements used by Mattia et al. (2019) and Venkatesh et al. (2012).

Public transport complement
Some studies considered the influence of a public transport subscription on car sharing usage (Becker et al., 2017; Münzel et al., 2019). To examine if the motives of car sharers could explain this influence, two statements about car sharing as a supplement to public transportation were included in the survey. The respondents were asked to indicate their agreement on a 5-point Likert scale to the following two questions: (1) 'I use shared cars to travel from a train station to my final destination' and (2) 'I use car sharing for trips where public transport is insufficient'.

Frequency of car sharing use
The frequency of car sharing use was measured by the number of reservations of the respondent in 12 months, from July 2022 to July 2023. The data were obtained by linking the survey responses to the reservation data of Greenwheels.

Measurement of the covariates
Several variables were measured in the survey to include them as covariates in the cluster model. Regarding the socio-demographic variables, household size, educational level and car ownership were included as survey questions. The household size was reported by the respondents as the count of individuals under 18 and those above 18 years old in the household. Educational level was measured as the highest attained educational level of the respondents.

Car ownership was measured at the household level, and respondents could indicate if their household had either: (1) no car, (2) one car or (3) two cars or more. The age of the respondents was not included as a survey question since this information was received by linking the survey responses to Greenwheels customer data.

As for the spatial characteristics, the residential density was defined in this thesis as the number of addresses per square km and was split into five different categories, in line with the categories defined by CBS (CBS, n.d.). The residential density was based on the respondents' 4-digit postal code, which was also received by linking the survey responses to the customer data. To obtain the parking facilities available to the respondents at their residence, respondents were asked to indicate which of the following situations applies to them: (1) having a private parking spot, (2) having free on-street parking available, (3) having paid/permit on-street parking available, (4) other, namely.

Furthermore, car sharing experience was measured by the individuals' membership duration in months. Whether or not that individual was an active member is not considered through the membership duration. However, as will be explained in the next section, several criteria were used to target active members for the survey. The membership duration was, as for age and the postal code received through linking the customer data to the survey responses. Lastly, the trip purpose was defined in the survey as the main trip purpose(s) for the car sharing trips of the respondents. The respondents could indicate a maximum of three main purposes for their car sharing trips. The purposes included were (1) groceries/shopping, (2) visiting friends/family, (3) sports/hobbies or entertainment, (4) vacation or weekend trip, (5) going from and to work or study, (6) picking up or dropping off goods, (7) other, namely.

Survey structure

As briefly mentioned, the survey questions needed for this research were part of a larger survey among Greenwheels users. Figure 3.1 shows the structure of the total survey. First, a brief introduction about the survey and its purpose was given. The second section presented the first questions, which were related to car ownership and a change in car ownership due to car sharing use. The third section asked about parking facilities and the location of shared cars. In the fourth section, questions regarding other types of car sharing services were asked. These questions were not used in this study. The fifth section asked respondents about their (shared) car usage; most of these questions were not used for this research. The sixth section consisted of statements that measured the motives and attitudes related to car sharing use. This section was followed by questions about respondents' public transport use in combination with car sharing use. Lastly, the survey ended with some socio-demographic questions. In total, the survey consisted of 43 questions, of which some were conditional on previous answers. All questions used for this research can be found in Appendix C

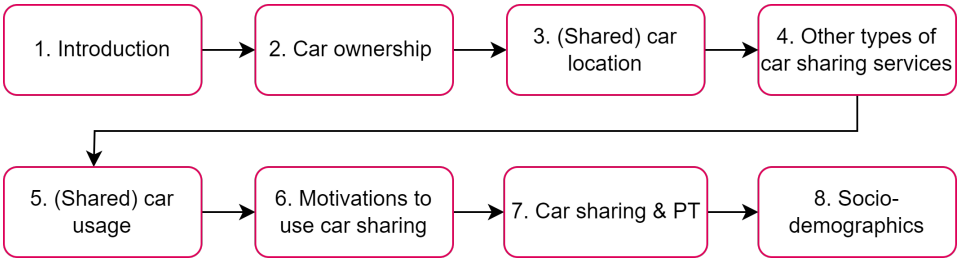

Figure 3.1: Survey structure

Survey distribution

Before the survey was distributed, it was tested by multiple people to check its comprehensibility and to ensure that individuals could complete the survey independently. After making some minor adjustments to enhance the clarity of the questions, responses were gathered from the 4th to the 16th of July. In consultation with Greenwheels, the following criteria were used to select members to whom the survey would be sent:

- The member had used Greenwheels at least twice
- The last ride was less than six months ago
- The member was Dutch-speaking

The first criterion was used to ensure that respondents were familiar with the concept of car sharing and could formulate accurate opinions about car sharing. The second criterion ensured that respondents could be regarded as active members who had recently used a shared car. In addition, this prevented inactive members from filling in the survey with unreliable or unfounded answers. Lastly, the selection of respondents was limited to Dutch-speaking members as the customer research of Greenwheels and the related survey questions were formulated in Dutch.

On the 4th of July, an invitation to participate in the survey was emailed to an initial group of 1350 Greenwheels members to test if any problems would arise while collecting responses. As this was not the case, the survey was sent to a larger group of 12223 members of Greenwheels on the 6th of July. To stimulate survey participation, participants could voluntarily enter a raffle for driving credits (10 times 50 euros). A total of 1393 responses were gathered, resulting in a response rate of 10.3%.

3.3. Latent Class Cluster Model

The previous chapter ended with the conceptual model, which, in fact is a graphical representation of the latent class cluster model used in this study. The latent class cluster model can also be formulated mathematically. This mathematical representation of the model, as formulated by Vermunt and Magidson (2016), is shown in equation 3.1.

$$P(y_{it} = m|z_i) = \sum_{x=1}^{K} P(x|z_i) \prod_{t=1}^{T} P(y_{it} = m|x) \tag{3.1}$$

An LCCA assumes that there is one nominal latent variable x that explains the correlations between the indicators t (Molin et al., 2016). That latent variable has K categories, which

are called classes or clusters. In equation 3.1, y_{it} represents the response of individual i on indicator t, which itself has m categories. In this case, all 16 indicators have 5 categories, so $m \in \{1, 2, 3, 4, 5\}$ and $t \in \{1, 2, ..., 16\}$. As stated earlier, the probability of belonging to a certain class is conditional on the covariates of that individual (Molin et al., 2016). The complete set of covariate values belonging to an individual i can be formulated as z_i.

The probability of observing a specific response set for individual i, conditional on the set of covariates of that individual, is basically the product of two probabilities. The first part of equation 3.1, $P(x|z_i)$, represents the probability of belonging to a certain latent class for the given individual's covariate values. This part is also considered to be the structural model. Subsequently, the second part of the equation, $P(y_{it}|x)$, represents the probability of observing a particular response for individual i on indicator t, conditional on the class membership x. This second part is considered to be the measurement model.

The conditional response probabilities $P(y_{it}|x)$ can be parameterised using the multinomial logit model as shown by Vermunt and Magidson (2016):

$$P(y_{it} = m|x) = \frac{exp(\beta^t_m + \beta^t_{mx})}{\sum_{m'=1}^{M} exp(\beta^t_{m'} + \beta^t_{m'x})} \tag{3.2}$$

Equation 3.2 shows that a set of category-specific parameters, β^t_m, and a set of class-specific parameters β^t_{mx} are estimated for each indicator. As the selected indicators are ordinal variables, the $\beta_{mx}t$ parameters are restricted for the categories of the indicators as follows (Vermunt & Magidson, 2016):

$$\beta^t_{mx} = \beta^t_x * y_m \tag{3.3}$$

This way, a single β coefficient is used for the indicator t per class x and is multiplied by the categories score m. Furthermore, all parameters are restricted using effect coding.

To obtain the probability of belonging to a certain latent class conditional on an individual's covariates values, the model again needs to be parameterised with a multinomial logit model (Vermunt & Magidson, 2016):

$$P(x|z_i) = \frac{exp(y_x + \sum_{r=1}^{R} y_{xr} * z_{ir})}{\sum_{x'=1}^{K} exp(y_{x'} + \sum_{r=1}^{R} y_{x'r} * z_{ir})} \tag{3.4}$$

Equation 3.4 shows that for every class K, of latent variable x, one base value, the intercept y_x is estimated (Molin et al., 2016). Furthermore, a set of regression parameters y_{xr} are estimated, which represent the effect of the covariate values (Molin et al., 2016). These parameters are restricted using effect coding.

The graphical representation of the model (Figure 2.9) also shows that the model consists of two different parts. Again, the structural model and the measurement part of the model can be seen. Unlike the indicators, the covariates are assumed to be correlated (Kroesen, 2021b). In addition, from the graphical representation of the model, it can be seen that causality runs from the covariates to the latent class variable. This implies that the included covariates are believed to influence the class membership of individuals. For the socio-demographic and

spatial characteristics, the causal direction is clear. However, the car sharing trip purpose and car ownership might both be influenced by the amount of car sharing use. Therefore, to avoid issues of endogeneity, meaning that a covariate is dependent on the variable it is trying to predict, car ownership and trip purpose are included as inactive covariates. As the membership length is assumed not to be influenced by any of the indicators, it is initially included as an active covariate. As such, the distribution of the categories of these covariates over the cluster can still be observed.

Application of the LCCA

To perform the LCCA, the software package LatentGOLD®5.1 was used. The first step of the model estimation is to determine the optimal number of latent classes, which will be done according to the statistical criteria discussed in the previous section. For the estimation of the latent classes, the statements that measure the respondent's attitudes on different motives to use car sharing are included as separate indicators. This means that no factor analysis will be used to construct latent factors as input for the LCCA. While constructing latent factors will likely reduce the number of indicators and, therefore, lead to a more parsimonious model, it also reduces the information about the influence of the considered motives. This holds especially if statements do not measure the same construct.

After the optimal number of classes is determined, or in other words, after the measurement model is estimated, the covariates are included in the model, which extends the model with its structural part. The included covariates are tested for their significance and, if necessary, removed from the model by means of backwards elimination. A detailed explanation of the model estimation is given in section 4.3.2.

3.4. Data preparation

To prepare the data for the analysis, responses with missing or incorrect data needed to be removed from the sample. To do so, the following steps were taken:

Table 3.1: Overview of steps taken to clean the data

Step	**Number of cases**	**Details**
1. Removing responses with incomplete data	72	Missing customer data (age, membership duration, reservations)
	25	Missing reservation data
	2	Missing postal code
2. Removing meaningless responses	6	Straightlining all questions about motives for car sharing use
3. Removing responses with outliers	2	Invalid household size (too high)
	1	Invalid household size (zero)
Total	*112*	

As can be seen in table 3.1, a total of 1281 valid responses remained after cleaning the data. To be able to analyse the data, the indicator responses needed to be re-coded from nominal into ordinal variables. In addition, some new variables, such as the total household size, were computed based on present variables. One additional data set containing the residential density for

every postal code in the Netherlands (CBS, 2022b) was linked to the sample data to determine the residential density of the respondents.

Furthermore, the ordinal variable 'frequency of car sharing usage' was created upon the number of reservations of the respondent. The following five categories were created:

Table 3.2: Categories of the created variable frequency of car sharing use

Categories	**Number of reservations**
Weekly or more often	>52
2-4 times per month	25-52
1-2 times per month	12-24
6-11 times per month	6-11
1-5 times per year	1-5

Lastly, among the reported trip purposes, a significant number of respondents stated that they use the shared car to visit a hospital, a general practitioner, or people they care for. Therefore, the trip purpose (health)care was added.

4
Data Analysis & Results

This chapter presents the analysis of the survey and the results following that analysis. Initially, a description of the characteristics of the survey sample is provided and compared to the characteristics of all Greenwheel members and to those of the Dutch population. Next, Section 4.2 presents general findings related to the total sample and their travel behaviour. The final section of this chapter describes the Latent Class Cluster Analysis and its results. The discussion of the results can be found in the next chapter.

4.1. Survey sample characteristics

First of all, it needs to be mentioned that the characteristics of all Greenwheels members are not shown in Table 4.1 due to the sensitivity of these statistics. However, the author had access to this information. Upon comparing the characteristics of the survey sample with those of all Greenwheels members, it became evident that the sample was not representative in terms of age. Specifically, the group of Greenwheels members comprised a higher share of individuals aged 18-40, while there was a smaller share of middle-aged (40-65) and old (65+) individuals compared to the sample composition. Regarding household size, the sample was not fully representative as a larger share of single-person households and a smaller share of 2-person households was present among all Greenwheel members. However, the differences were rather small. Regarding educational level, the sample could be regarded representative for all Greenwheels members. For residential density and car ownership, the statistics of all Greenwheels members were not available, and thus, these characteristics could not be compared.

In Table 4.1, the characteristics of the survey sample are outlined and compared to those of the Dutch population. This comparison was used to showcase the socio-demographic characteristics of the sample, which was comprised of station-based car sharers. It should be noted that because the survey sample only included station-based car sharing members, the purpose of comparing it to the Dutch population is not to determine its representativeness but rather to highlight the differences between the two groups. Furthermore, the sample characteristics are compared with the findings of other car sharing studies. The information on the Dutch population was sourced from Statistics Netherlands.

The sample differs from the Dutch population as it comprises fewer young individuals. However, as stated before, young people are underrepresented when controlling for all Greenwheels members. Therefore conclusions regarding age should not be generalised to the whole (car sharing) population.

Table 4.1: Socio-demographics characteristics in sample and population

	Survey sample		**Population**
Age *(CBS, 2023d)*	**Count**	**%**	**%**
18-30	96	7.5	15.9
30-40	190	14.8	16.2
40-65	718	56.0	44.8
65+	277	21.6	23.2
Total	*1281*	*100*	*100*
Education level*, *(CBS, 2023a)*	**Count**	**%**	**%**
None/Primary education	5	0.4	7.2
Secondary education & MBO1	83	6.5	29.1
MBO2-4	70	5.5	26.4
HBO/WO	1073	83.8	36.6
I would rather not say/Unknown	50	3.9	0.7
Total	*1281*	*100*	*100*
Household size, *(CBS, 2023b)*	**Count**	**%**	**%**
1	366	28.6	39.5
2	534	41.7	32.4
3	165	12.9	11.6
4	143	11.2	11.6
5+	73	5.7	5.0
Total	*1281*	*100*	*100*
Residential Density, *(CBS, 2022b)***	**Count**	**%**	**%**
Very highly urban	973	76.0	23.9
Highly urban	229	17.9	27.6
Moderately urban	54	4.2	17.4
Little urban	18	1.4	16.4
Non-urban	7	0.5	14.7
Total	*1281*	*100*	*100*
Car ownership within household, *(Zijlstra, Bakker, et al., 2022)*	**Count**	**%**	**%**
0	1105	86.3	26.0
1	164	12.8	47.0
2+	12	0.9	27.0
Total	*1281*	*100*	*100*

*Sample compared to population of 15-90 years old
** Sample compared to population of 15 years and older

Regarding the education level, the survey sample differed substantially from the Dutch population. Within the survey sample, 83.8% of the respondents were highly educated (HBO/WO) compared to only 36% of all Dutch people. The high level of highly educated was in line with previous findings in the literature that suggested that highly educated people are more likely to use car sharing services (Amirnazmiafshar & Diana, 2022; Millard-Ball et al., 2005; Münzel et al., 2019). It is possible that the high percentage of individuals with higher levels of education (HBO/WO) in the study was due to the fact that shared cars were more prevalent in major Dutch cities, particularly in and around the Randstad. According to CBS data, these regions

also have a higher concentration of highly educated people (CBS, 2021). Figure 4.1 displays a heat map indicating the municipalities of respondents. This map confirmed that most participants live in and around the Randstad and other large cities in the Netherlands.

When comparing the household sizes within the sample to those of the Dutch population, a noticeable difference was found between single-person and 2-person households. However, this was a similar difference as identified between the sample and all Greenwheels members. Regarding the larger household sizes, only minor differences were observable between the sample and the population. It is interesting to note that no substantial differences in shares of small households are present in the sample as literature on car sharing membership often finds a positive influence of small household size on membership (Ceccato & Diana, 2021; Prieto et al., 2017). However, the average household size in other studies on car sharing membership was often around two persons, which was also the largest group present in this sample (Amirnazmiafshar & Diana, 2022).

The distribution of the residential density corresponding to the 4-digit postal code of the respondents differed substantially from that of the Dutch population. When comparing the sample to the population, it became apparent that almost all respondents, in total nearly 94%, resided in (very) highly urbanised areas. While the sample differed substantially from the population, it aligned with findings in the literature, which identified a positive influence of a higher residential density on the adoption of car sharing services (Aguilera-García et al., 2022; Hjorteset & Böcker, 2020). Additionally, it is important to note that the residential density of the survey sample was evidently strongly affected by the spatial distribution of the shared cars of Greenwheels, which are more present in the large Dutch cities. Looking at the heat map of the respondents shown in Figure 4.1, it can be seen that the respondents indeed resided in these areas.

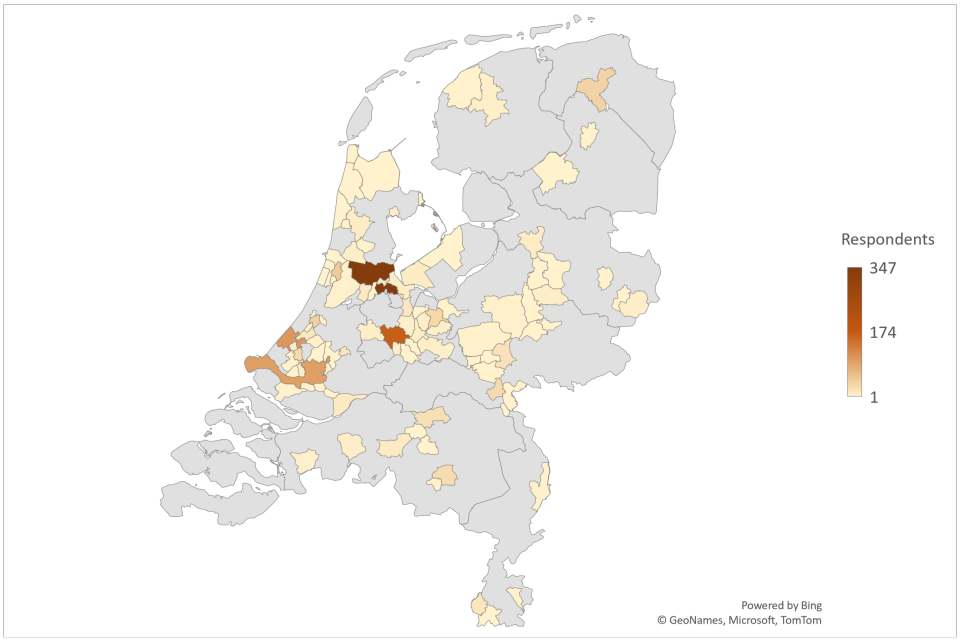

Figure 4.1: Heatmap of the municipalities of the respondents

Lastly, car ownership within in survey sample was found to be much lower in the sample com-

pared to the Dutch population. Within the sample, 86.3% did not own a car compared to 26% in the population. This is in line with findings in the literature that indicated that car ownership has a negative influence on car sharing usage (Aguilera-García et al., 2022; Becker et al., 2017).

To conclude, the sample was not representative of all Greenwheels members in terms of age and household size. The difference in age between the sample and all Greenwheels members was more substantial than the difference in household sizes. Therefore, especially the findings related to age should not be generalised to the whole station-based car sharing population. Furthermore, the comparison of the sample with the average Dutch population (that has a driving license) showed that they differed substantially. However, as this research aims to find distinct groups of car sharers, these disparities do not pose a concern for the forthcoming analysis. Nonetheless, this information provides additional context for the results of the analysis in this research.

Car sharing usage frequency

Table 4.2 shows the distribution of car sharing use, based upon the number of reservations, within the sample. It can be seen that the largest group in the sample only incidentally used the shared car. However, as higher usage frequencies are also substantially represented in the sample, the chosen categories are regarded as suitable for further analyses.

Table 4.2: Car sharing usage frequency

Usage frequency	**Count**	**%**
Weekly or more often	127	9.9
2-4 times per month	213	16.6
1-2 times per month	300	23.4
6-11 times per year	294	23.0
1-5 times per year	347	27.1
Total	*1281*	*100*

Membership length distribution in the sample

Figure 4.2 shows the distribution of the membership length of the respondents. It can be seen that the total membership length in the sample varies from 0 to 22 years. The distribution is positively skewed, meaning that most respondents have a membership length on the shorter range of the spectrum. The median membership length within the sample is 4.7 years, and the mean membership length in the sample is 7.0 years.

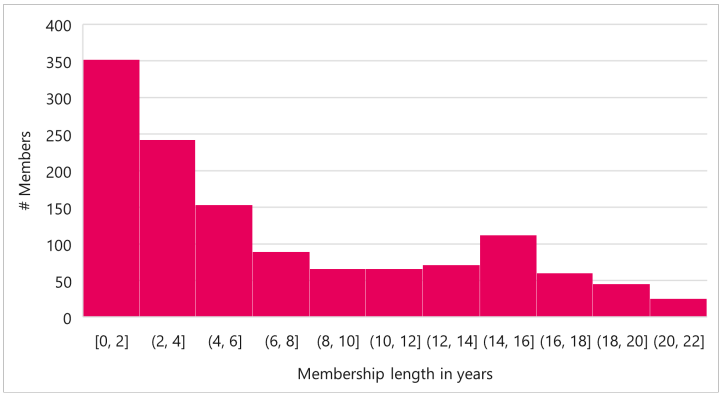

Figure 4.2: Membership length within sample

4.2. Differences in membership length and usage frequency relations in the sample

This section presents multiple analyses aimed at revealing trends within the sample as a whole. First, an analysis is conducted on members with different membership lengths to identify potential differences between novel and long-term members. Subsequently, multiple analyses regarding differences in car sharing usage frequencies of the members are presented to examine whether variations exist at the aggregate sample level.

Characteristics of members with varying membership lengths

Based upon the literature review and, more specifically, the Diffusion of Innovation theory (Rogers, 2003), it was concluded that the socio-demographic characteristics associated with the car sharing population often correspond with the typical characteristics of innovators and early adopters. As the number of car sharers and shared cars have been increasing rapidly over the past years, it raises the question if the user profile of more recent car sharing members differs from those who have been a member for a longer period (CROW, 2023). Table 4.3 compares three different user groups with varying car sharing membership duration.

Some interesting differences can be identified when reviewing the comparison in table 4.3. To begin with, the percentage of highly educated (HBO/WO) individuals is nearly 20% lower in the group with the shortest membership duration (1-2 years) compared to the group of members with over ten years of membership. While the first group still consists of 70% highly educated individuals, the share of lower-educated members appears to increase over time. A similar trend is observed in the residential density of car sharing members. More recent car sharers appear to reside in less densely urban areas compared to long-term members. However, it is important to note that the spatial distribution of shared cars might also influence this pattern. There is a possibility that more new shared cars are being placed in less urban areas compared to a decade ago. When considering the age of members, differences in their current age exist between the groups, but the average age at the time of becoming a member does not differ substantially. Lastly, no substantial variations in average household size are found among the different groups.

Besides the discussed socio-demographic characteristics, the differences in car ownership, the number of disposed cars after starting car sharing, and the driven car sharing kilometres are compared. Car ownership appears to be slightly lower for long-term members. This may be explained by the fact that the number of disposed cars after starting car sharing is slightly higher for those with longer membership duration. Lastly, the average driven car sharing kilometres (from July 2022 to July 2023) is higher for those who are long-term car sharing members.

Regarding motives for car sharing, little differences are found between short, medium and long-term members. A complete overview of the scores on all different motives can be found in Table D.1 in Appendix D. Considering the little differences, long-term members seem to be slightly more motivated through environmentally and utility-related aspects. The motives 'influence of others' and 'joy of driving' show an opposite relation, as it decreases slightly with membership length. Lastly, a slight increase in public transport related motives, such as 'instead of insufficient PT' is found.

Altogether, the results indicate that new car sharing members differ from long-term ones because they tend to have lower levels of education and reside in less densely populated urban areas compared to their long-term counterparts. While more recent members show less car sharing use, almost 24% of these members intend to increase their usage in the future. This could be an indication that car sharing is diffusing and larger parts of the population are being attracted to car sharing services. However, it is important to note that this data only reflects a single moment in time. Therefore, it is not possible to determine whether new members truly differ from new members ten years ago or whether factors such as higher education levels are related to longer memberships.

Table 4.3: Car sharing member profiles for different membership duration

Membership duration *% of total sample*	**1-2 years** *(27%)*	**2-10 years** *(43%)*	**10+ years** *(30%)*
Age (mean)			
Currently	47	50	60
When membership started	46	45	45
Household size (mean)	2.31	2.36	2.39
Education level (%)			
Non/Primary education	0.9	0.4	0.0
Secondary education	12.8	4.7	3.4
MBO2-4	10.7	4.0	2.9
HBO/WO	69.9	87.2	91.4
Unknown	5.8	3.8	2.3
Car ownership (%)			
0	82.3	88.4	86.7
1	16.2	11.2	12
2 or more	1.4	0.4	1.3
Car disposed (%)			
0	73.3	70.5	69.5
1	25.5	28.9	29.8
2 or more	1.2	0.5	0.8
Residential density (%)			
Very highly urban	70.4	76.3	80.4
Highly urban	20	19	14.4
Moderately urban	6.4	3.1	3.9
Little urban	2.6	1.1	0.8
Non-urban	0.6	0.5	0.5
Usage frequency (%)			
Weekly or more often	6.4	11.6	10.7
2-4 times per month	15.9	17.4	16.2
1-2 times per month	23.2	22.1	25.6
6-11 times per month	32.8	18.6	20.4
1-5 times per year	21.7	30.4	27.2
Car sharing kilometers (mean)	783	1011	1167
Intention to use car sharing in the future (%)			
Much more often	1.5	0.9	0.6

More often	23.8	13.6	10.4
Equally often	65.2	76.1	80.4
Less often	6.7	6.7	7.6
Much less often	2.9	2.7	1.1
Motives (mean 1-5)			
To reduce traffic	3.43	3.52	3.84
Cheaper than a private car	4.34	4.51	4.50
Influence of others	3.03	2.93	2.87
Joy of driving	3.12	2.73	2.54
Use is easy	4.28	4.28	4.37
Instead of insufficient PT	4.30	4.40	4.61

The relation between car sharing trip purpose and car sharing usage frequency

Since respondents were asked about their main car sharing trip purposes, it is possible to assess whether or not these trip purposes vary for different car sharing usage frequencies. First, Figure 4.3 shows the total distribution of trip purposes in the sample. This figure shows that 'visiting friends or family' and 'picking up and dropping off goods' are the two most frequently mentioned trip purposes. In addition, figure 4.4 shows the distribution of car sharing trip purposes for the five different car sharing usage frequencies. Reviewing this figure, it becomes clear that for increasing car sharing usage, the share of the trip purpose 'picking-up and dropping-off goods' decreases. Additionally, the share of the trip purpose 'Sports, hobby and entertainment' increases with higher usage frequency. The trip purposes 'Visiting friends or family' and 'Vacation or Holiday' show a similar increase, except for the highest usage frequency.

Reviewing the relation between car sharing trip purposes and usage frequency, it can be concluded that most trip purposes can be considered occasional. Although a slight increase in more frequent activities such as sports/hobby/entertainment and a decrease in occasional activities such as transporting goods can be seen for higher usage frequencies, the majority of trip purposes can still be considered occasional. To that extent, it is interesting to review which modalities are being replaced by the station-based shared car and to what extent different usage frequencies influence this. This will be discussed in the next section.

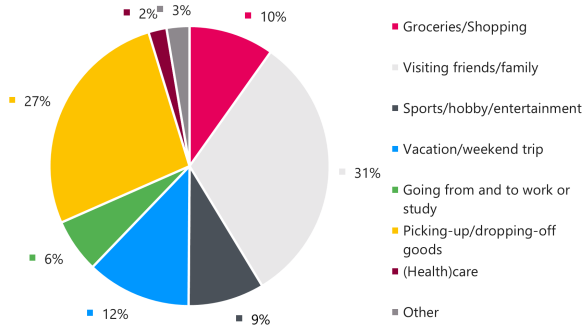

Figure 4.3: Main car sharing trip purposes within the sample

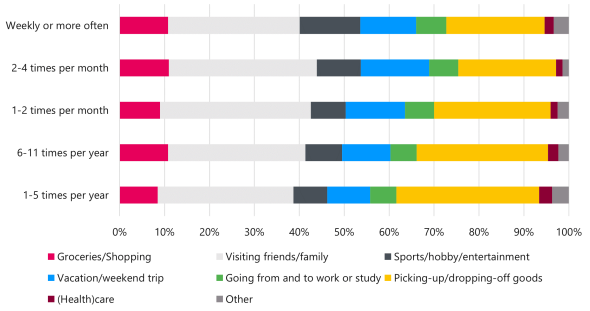

Figure 4.4: Main car sharing trip purposes for different car sharing usage frequencies

The substitution of car sharing trips

In the survey, respondents were asked a hypothetical question about the most likely alternative transportation mode they would have used if they could not use a shared car from Greenwheels for their trips. This question aimed to explore the mode substitution effect of car sharing trips. Figure 4.5 presents the distribution of transportation modes. Reviewing Figure 4.5, it becomes apparent that car sharing trips mainly substitute public transport and private car trips.

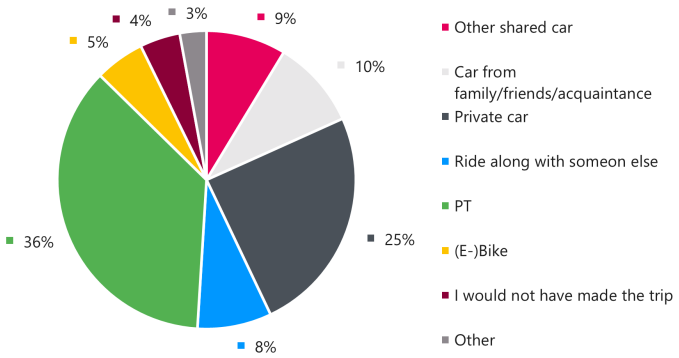

Figure 4.5: Hypothetical alternative transportation mode of car sharing trip

As Figure 4.5 only presents information about the whole sample, the hypothetical mode substitution of car sharing trips for different usage frequencies is presented in Figure 4.7. When comparing different usage frequencies, it is noticeable that the relative share of 'private car' increases as the car sharing usage frequency increases and that the share of public transport decreases as the car sharing usage frequency increases. In addition, the mode substitution is weighted for the number of reservations to examine the total substitution effect. In this case, the share of private car even exceeds that of public transport in the whole sample.

Therefore, it can be argued that station-based shared cars mostly replace private car trips, followed by public transport trips. The fact that higher car sharing use is related to a higher substitution effect of private car trips suggests that frequent users are more car-dependent than those who use the shared car occasionally. To explore whether occasional car sharing members are indeed less car-oriented than their high-usage counterparts, the relationship between car sharing use and public transport use will be discussed in the next section.

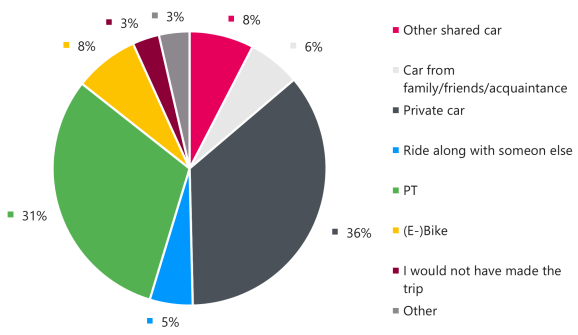

Figure 4.6: Substitution of CS trip weighted for use

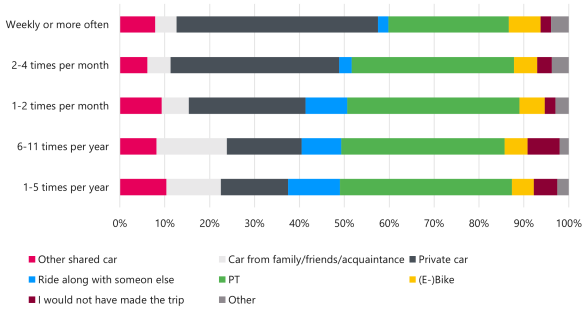

Figure 4.7: Substitution of CS trip for different usage frequencies

Relation between car sharing usage and public transport usage

To further analyse the relationship between car sharing use and public transport, the self-reported public transport use of the respondents is analysed. Figure 4.8 presents the public transport use within the sample. This figure shows that more than half of the sample, 52%, uses public transport at least one day per week, which is substantially higher than the Dutch average (CBS, 2023c). In addition, figure 4.9 compares the distribution of public transport use for different car sharing usage frequencies. From this figure, it becomes apparent that the amount of public transport use is higher for those who use the shared car less often. Reflecting on the substitution effect of shared cars, it can be concluded that the high share of public transport for the occasional car sharers can, to some extent, be attributed to this group's high public transport use in the first place.

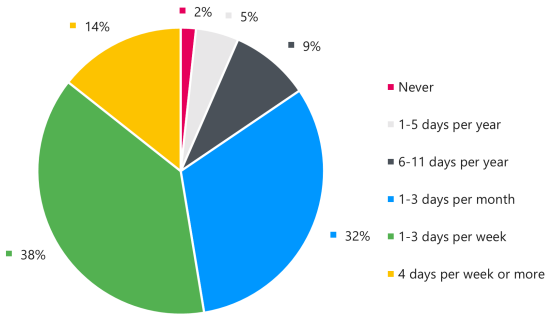

Figure 4.8: Public transport use within the sample

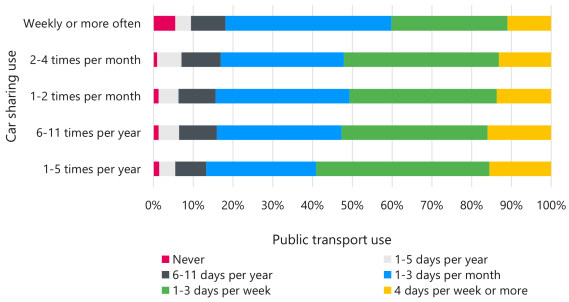

Figure 4.9: Public transport use for different car sharing usage frequencies

In conclusion, when examining the aggregate findings for Greenwheels car sharers in the sample, the analyses reveal that the typical station-based car sharer resides in highly urbanised areas, is highly educated, and does not own a private car. The main trip purposes for car sharers are visiting friends and family and transporting goods. As car sharing use intensifies, the typical occasional trip purpose decreases while purposes related to daily activities increase. When weighted for their usage, car sharing trips mostly replace private car trips followed by public transport trips. The substitution of public transport trips is higher for members with lower char sharing use. However, their initial public transport use is also higher, especially compared to the Dutch average. These results provide meaningful insights about the sample as a whole but do not account for individual variations. Therefore, the next sections will explore whether different user groups exist within the sample and what characterises them.

4.3. Latent Class Cluster Analysis

The analysis conducted in the previous section provides insights into the total sample of station-based car sharers. The Latent Class Cluster Analysis (LCCA) performed in this section extends these findings by revealing different car sharing user profiles present in the sample. This section starts by describing the model specification and estimation process. Subsequently, the last subsection shows the results of the LCCA by presenting the identified clusters.

4.3.1. Model specification

The LCCA was performed using the indicators and covariates shown in figure 2.9. First, the measurement model was estimated with different numbers of clusters, ranging from one to ten clusters, to be able to select the model with the optimal number of clusters. Before estimating the model, the scale-type of the indicators had to be specified in LatentGold. All the included indicators, i.e. all statements and the usage frequency, were specified as ordinal variables in LatenGold. Furthermore, some default technical estimation settings of LatentGold were changed. More specifically, the start values for the estimation had been changed to prevent estimating a model with a local optimum. For both the estimation of the initial measurement model and the measured model combined with the structural model, the number of random sets of starting values was increased to 160 and the number of iterations for each set to 250.

After the measurement model had been estimated, the model was extended by adding the structural part, the covariates, to the model. As for the indicators, the scale type of the active covariates needed to be specified when extending the measurement model with the structural model. The covariates age, household size and membership length were specified as numeric variables, while residential density, education level and parking facilities were specified as nominal. After estimating the complete model, the significance of the covariates was checked. Insignificant covariates were made inactive by means of backwards elimination, starting with the most insignificant covariate. As covariates are assumed to be correlated, the significance of covariates may change if another covariate is removed from the model. Therefore, the covariates were removed one at a time, starting with the most insignificant covariate.

4.3.2. Model estimation

As discussed in section 3.1, various statistical criteria are available to determine the number of clusters. In Table 4.4, the model fit statistics are shown for the different measurement models, ranging from one to ten clusters. As can be seen, the p-value of the likelihood-ratio chi-squared statistic L^2 was smaller than 0.05 for all models, indicating that all models would be rejected based on this criterion. However, as mentioned in section 3.1, this statistic should not be used in case of sparse data. Since the estimated model included 16 variables, of which each has five categories, there were 5^{16} possible response patterns, and thus many cells remained empty. However, the BIC- and AIC-values could be estimated and are shown in table 4.4. It can be seen that the AIC-value continued to decrease as the number of clusters increased, indicating that a 10-cluster model would be statistically optimal. However, when reviewing the BIC-values, the lowest value was found for the 7-cluster model. Taking the BVR-values into consideration did not provide additional support for a specific number of clusters since large BVR-values (>3.84) were present in all models. Another criterion to determine the number of classes is to review the cluster sizes, as usually cluster sizes of at least 5% of the sample are desired to assure the interpretability of the clusters (Weller et al., 2020). The smallest cluster size for the 7-cluster model was 2.3%, thus violating the rule of thumb of 5%. As the 6-cluster model proved to have sufficiently big cluster sizes and provided meaningful clusters for the interpretation, this model was selected.

Table 4.4: Model fit statistics for different numbers of clusters

No. of clusters	Npar	LL	L^2	p-value	BIC(LL)	AIC(LL)	Max BVR	Smallest cluster
1	64	-27986.2	37643.1	0.00	56430.4	56100.5	805.5	100.0 %
2	81	-27240.2	36151.1	0.00	55060.0	54642.4	199.4	39.6%
3	98	-26899.0	35468.6	0.00	54499.2	53993.9	141.8	15.2%
4	115	-26719.7	35110.1	0.00	54262.3	53669.4	82.7	13.9%
5	132	-26580.0	34830.6	0.00	54104.5	53424.0	52.4	7.4%
6	149	-26483.5	34637.6	0.00	54033.1	53264.9	47.4	**6.6%**
7	166	-26406.8	34484.2	0.00	**54001.3**	53145.5	45.1	2.4%
8	183	-26356.6	34383.8	0.00	54022.6	53079.1	41.3	2.2%
9	200	-26307.2	34285.1	0.00	54045.6	53014.5	45.1	2.2%
10	217	-26257.1	34184.9	0.00	54067.0	**52948.3**	41.4	2.1%

Adding the covariates to the 6-cluster extended the measurement model with a structural model. As mentioned in section 3.1, the significance of the covariates was tested with the Wald-statistic. After adding all the initially selected active covariates present in figure 2.9, two covariates, education level and residential density, had a p-value > 0.05 based on the Wald-statistic. The variable with the largest p-value, education level, was made inactive and, therefore, no longer influenced class-membership. Consequently, the model was re-estimated with the remaining covariates. As residential density remains insignificant, with a p-value of 0.44, it was also made inactive. After re-estimating the model again, all covariates had a significant p-value, indicating that they significantly influence class-membership. Lastly, the entropy R^2 of the total model was checked to assess to what extent the model accurately assigns the individual cases to the six clusters. The final latent class cluster model had an entropy R^2 of 0.77, which was slightly lower than the desired 0.80 but still sufficient. In addition, the standard r-squared for the covariates was 0.05, indicating that only a small portion of the variability in class membership was explained by the included covariates.

4.3.3. Results

After analysing the cluster profiles, which can be found in Table 4.5, of the six different clusters, the following names have been defined for each cluster:

- Cluster 1: Moderately motivated car sharers
- Cluster 2: Utility-focused car sharers
- Cluster 3: Environmentally motivated frequent car sharers
- Cluster 4: Highly conscious car sharers
- Cluster 5: Environmentally-sceptic utility-focused car sharers
- Cluster 6: Sceptical occasional car sharers

To get a first understanding of the cluster differences and similarities, Figure 4.10 graphically represents the mean indicator scores of all six clusters. In this figure, differences between the six clusters can be seen already. Besides the differences between the clusters, some general trends of the indicators can be identified. For example, the differences in the indicator scores of the six clusters on the environmental-related statements are clearly visible and substantial. On the contrary, for other statements, such as 'Cheaper than owning a private car', the differences are less substantial. It can be seen that for all clusters, the costs are regarded as an important motivation. Similarly, the indicator scores on the statements related to the experienced effort to

use car sharing are quite high for all clusters (Note that the statement 'Shared car not available' is negative, and thus a low score is considered positive). Moreover, all clusters show a high indicator score on the statement 'Instead of insufficient PT'. On the contrary, the mean indicator score on the statement 'As a last-mile solution for a train trip' is very low for all clusters, indicating that this is generally not a primary motivation to use shared cars. Lastly, on the statement 'Joy of driving', the mean indicator scores of all clusters are very average. This indicates that most members neither agree nor disagree with the statement that the joy of driving is a motivation to use car sharing.

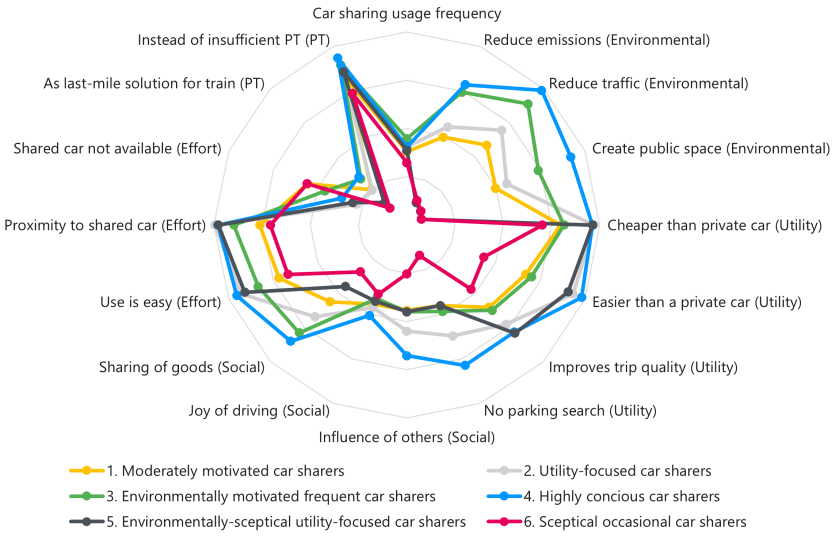

Figure 4.10: Indicator scores (mean) for the six different clusters

In Table 4.5, the complete profile of all six clusters can be found. The Table includes the mean scores of the indicators, the active covariates and the inactive covariates. The p-value of the indicators and active covariates can be found in Table D.2 in Appendix D. In addition, some variables are included in Table 4.5 as inactive covariates that were not present in the conceptual model (see Figure 2.9). These variables are the number of disposed cars after starting car sharing, car sharing trip substitution and the driven car sharing kilometres. These variables have been included as they provide additional information and context for the identified clusters. A visual summary of the clusters can be found in Figure 4.11, which gives a simplified overview of the clusters as not all aspects are present. In this overview, the included indicators are colour-scaled from green to red to indicate the mean indicator score within that cluster. A green indicator represents a high score, whereas a red indicator represents a low score.

Table 4.5: Cluster profiles of the 6-cluster model

	Cl.1	Cl.2	Cl.3	Cl.4	Cl.5	Cl.6	Sample
Cluster size	32%	23%	19%	12%	7%	7%	
Indicators (mean)							
Usage frequency	2.52	2.62	2.79	2.62	2.55	2.29	2.59
Environmental motives							
Reduce emissions	2.97	3.20	3.98	4.15	1.50	1.55	3.15
Reduce traffic	3.34	3.78	4.55	4.95	1.40	1.41	3.59
Create public space	2.99	3.24	3.95	4.68	1.32	1.32	3.20
Utility motives							
Cheaper than a private car	4.19	4.88	4.26	4.85	4.85	3.81	4.46
Easier than a private car	3.67	4.73	3.80	4.92	4.62	2.73	4.09
Improves trip quality	3.41	3.91	3.50	4.14	4.17	2.88	3.65
No parking search	2.81	3.49	2.94	4.15	2.81	1.68	3.07
Social motives							
Influence of others	2.77	3.20	2.80	3.71	2.80	2.01	2.94
Joy of driving	2.77	2.85	2.65	3.03	2.71	2.55	2.78
Sharing of goods	3.25	3.69	4.16	4.41	2.80	2.37	3.57
Experienced effort to use							
Use is easy	3.87	4.72	4.34	4.82	4.64	3.67	4.31
Proximity to shared car	4.05	4.98	4.59	4.92	4.91	3.83	4.51
Shared car not available	3.23	2.13	2.84	2.46	2.22	3.24	2.74
Public transport motives							
As last-mile solution for a train trip	2.04	2.02	2.35	2.41	1.66	1.50	2.08
Instead of insufficient PT	4.27	4.52	4.59	4.75	4.44	3.95	4.44
Active covariates							
Age *(mean)*	50	54	53	57	48	48	52
Membership length in months *(mean)*	66	99	96	99	89	49	83
Household size *(%)*							
1	27	36	19	29	33	32	29
2	40	45	42	44	40	37	42
3	15	12	12	11	12	14	13
4+	18	7	27	15	16	17	17
Mean	2.3	1.9	3.1	2.2	2.3	2.2	2.3
Parking facility available *(%)*							
Paid/permit on-street parking	50	74	52	78	71	38	60
Free on-street parking	33	17	26	18	15	32	25
Private parking spot	16	8	21	5	11	30	14
Other	1	2	1	0	2	0	1
Inactive covariates							

Car ownership *(%)*							
0	80	92	90	95	89	68	86
1	19	7	10	5	11	28	13
2+	1	1	1	1	0	3	1
Car disposed after car sharing *(%)*							
0	74	73	66	59	85	70	71
1	26	26	33	40	13	27	28
2 or more	0	1	1	1	1	3	1
Education *(%)*							
None/primary education	0	0	1	1	0	0	0
Secondary education/MBO1	7	7	5	5	8	8	6
MBO2-4	5	6	5	6	5	5	5
HBO/WO	82	84	86	85	87	79	84
I would rather not say	6	3	3	3	0	8	4
Residential Density *(%)*							
Very highly urban	67	85	73	85	86	66	76
Highly urban	25	11	19	11	9	23	18
Moderately urban	4	3	5	4	3	9	4
Little urban	2	1	2	0	2	0	1
Non-urban	1	0	0	0	0	2	1
Main car sharing trip purposes (*% answered yes*)							
Groceries/shopping	22	23	16	15	20	28	21
Visiting friends/family	61	67	70	72	72	60	66
Sports/hobby/entertainment	19	15	20	17	24	19	18
Vacation or weekend trip	32	28	30	33	20	11	25
Going from and to work or study	14	10	15	11	15	14	13
Picking-up/dropping-off goods	55	58	30	56	54	50	56
(Health)care	4	5	3	6	4	4	4
Other	5	5	5	4	5	10	6
Car sharing trip substitution *(%)*							
Shared car from other company	8	10	8	8	8	10	9
Car from family/friend/acquaintance	11	8	10	7	8	12	10
Private car	25	19	31	24	17	32	25
Ride along with someone else	8	9	5	10	9	9	8
Public Transport	33	40	36	41	49	23	36
(E-)bike	7	5	3	5	2	8	5
I would not have made the trip	5	5	5	1	5	3	4
Other	3	4	2	3	1	3	3
Car use after car sharing *(%)*							
More	28	31	23	20	45	19	27
Equal	34	30	35	34	34	46	34
Less	38	40	42	46	21	35	39
Car sharing kilometres *(mean)*	877	940	1270	1146	1018	703	996
Number of reservations *(mean)*	18.8	20.5	23.3	22.6	20.4	17.7	20.6

Cluster 1: Moderately motivated car sharers

The first identified cluster consists of 32% of the sample and is the largest of all clusters. Members of this cluster are identified as 'Moderately motivated car sharers' since they do not distinguish themselves from the other clusters through specific high or low scores on the indicators. Regarding the environmental motives for using car sharing, the members of this cluster are rather indifferent and do neither agree nor fully disagree with the statements. While the members of this cluster rate the utility-related statements slightly positive, their scores are rather low compared to the other clusters. The same applies to the statements related to the experienced effort to use shared cars.

With an average membership length of 66 months, members of this cluster are car sharing members for a shorter period than most other clusters. Besides this, the first cluster has the second highest car ownership, with 20% of its members owning at least one car. Compared to the other clusters, members of cluster one reside less in very highly urban areas and more often in highly urban areas. Regarding the main car sharing trip purposes, members of this cluster use the shared car more often for a vacation or weekend trip compared to the other clusters. In addition, while still being the most reported trip purpose, visiting friends or family is reported relatively less often within this cluster.

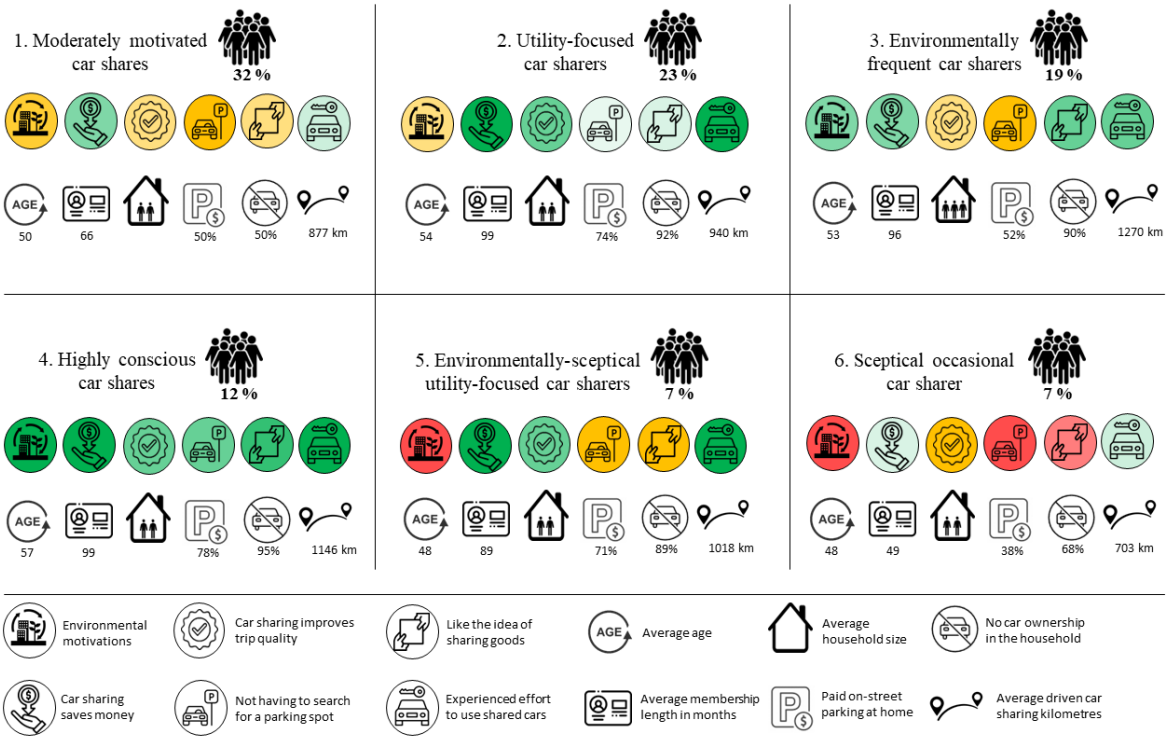

Figure 4.11: Visualisation of the clusters

Cluster 2: Utility-focused car sharers

The second cluster consists of 23% of the sample and its members are identified as "Utility-focused car sharers". Members of this cluster rate the utility-related motives to use shared cars high and in particular the cost-related motive, which has the highest score of all clusters. In comparison to the other clusters, this cluster scores average on the three statements about

the environment. What is interesting to note is the very positive scores on the statements related to the experienced effort it takes to use shared cars. Furthermore, the members in the cluster are characterised by a long average car sharing membership duration (99 months) and by having the highest shares of 1- and 2-person households (36% and 45%). The parking facilities available to the members of this cluster are predominantly paid or permit on-street parking (74%). Therefore, it might not be surprising that within this cluster, 92% do not own a private car, which is even higher than the average 86% in the sample. This may also explain the relatively low share of car substitution (19%) compared to the other clusters.

Cluster 3: Environmentally motivated frequent car sharers

Members of the third cluster are identified as the 'Environmentally motivated frequent car sharers' and make up 19% of the sample. The usage frequency of this cluster is the highest of all clusters. Regarding the other indicators, this cluster distinguishes itself from the other clusters by scoring high on environmentally-related motives while scoring lower on utility-related motives. This could indicate that members of this cluster make a conscious choice, based on their attitudes related to the environment, to use shared cars. In addition, the low score on the joy of driving and the high score on the preference for sharing goods could support this.

The members in this cluster typically live in the largest households of the sample with an average size of 3.1 persons, and compared to the other clusters slightly fewer members live in very highly urbanised areas (73%). It is interesting to note that while members of this cluster have an above-average share of free on-street (26%) and private parking facilities (21%) available to them, car ownership remains low (90% do not own a car). Furthermore, 34% of the members in this cluster have disposed of at least one private car since they started using Greenwheels, and they show a high car sharing trip substitution for the private car (31%). Lastly, members of this cluster use the car shared car substantially less for 'picking up or dropping off' goods and 'shopping or groceries' than the other clusters.

Cluster 4: Highly conscious car sharers

The fourth cluster comprises 12% of the sample, and its members are identified as 'Highly conscious car sharers'. Members of this cluster score very high on all environmental- and utility-related statements, indicating that their car sharing usage is motivated by those aspects. This cluster distinguishes itself from the third cluster by the high values on the utility-related motives. Furthermore, members of this group scored very high on the statement related to the sharing of goods, which could indicate that the usage of shared cars is a deliberate choice they make. The fact that members of this cluster also consider the use of shared cars the easiest of all clusters suggests that they are aware and in control of their choice to use car sharing services. Surprisingly, members of the fourth cluster also have the highest score for the motivation "Joy of driving". However, it should be noted that this score is still average on the used scale (1-5), indicating that they still do not regard it an important motivation to use car sharing services.

The highly conscious car sharers are the oldest of all clusters with an average age of 57, and together with the second clusters, they are also Greenwheels members for the longest period (99 months). At their residences, 78% of members within this cluster have paid or permit on-street parking available to them, which is the highest percentage of all clusters. This could also explain the fact that this cluster has the highest score on the indicator related to not having to search for a parking spot when using a (station-based) shared car. Furthermore, car ownership

within the cluster is the lowest of all clusters, with only 6% owning a car. In addition, 41% of the members have disposed of at least one car after they start using car sharing, which is the highest percentage of all clusters. Lastly, while the car sharing usage frequency of cluster four is similar to that of the second cluster, members in the fourth cluster drive more kilometres (1146 compared to 940). A possible explanation might be that members of this cluster, compared to the second cluster, indicate that their main car sharing trip purpose is more often a vacation or weekend trip and less often groceries or shopping, which are usually shorter trips.

Cluster 5: Environmentally-sceptical utility-focused car sharers

The fifth cluster consists of 7% of the sample, and its members are identified as 'Environmentally-sceptical utility-focused car sharers'. For the members of this cluster, the environmentally related statements are no motivation at all to use car sharing as all three related statements are rated very low. The utility-related statements, except for not needing to search for a parking spot, are rated high by the members of this cluster. Compared to the other clusters, the members of this cluster do not like the idea of sharing goods as much. Reviewing all the scores on the indicators of this cluster suggests that its members mainly use the shared car because it benefits them in terms of money, effort and trip quality.

Together with the sixth cluster, the members of this cluster are, on average, the youngest of all (48 years). However, different from cluster six, members of this cluster are, on average, car sharing members for a longer period (89 months compared to 49). It is interesting to note that while 74% of the members of this cluster have paid or permit on-street parking available to them, they indicate that not needing to search for a parking spot is not a motivation to use car sharing for them. When reviewing the level of car ownership, it is noticeable that while car ownership is low, the amount of disposed cars after starting using car sharing is 14%, which is the lowest of all clusters. This suggests that car ownership was already low before using car sharing, which could explain the fact that 49% of this cluster indicates that they would have used public transport if they could not have used a Greenwheels shared car. In addition, only 17% of this cluster indicates that they would have used a private car if they could not have used a Greenwheels shared car, which is the lowest of all clusters. Together, this suggests that members of this cluster are typically car-less individuals and that car sharing enables them to use a car when they need one. This is supported even more by the fact that this cluster is the only cluster in which more individuals (45%) indicate that their car usage has increased instead of decreased (21%) after starting car sharing.

Cluster 6: Sceptical occasional car sharers

Members of the sixth cluster are labelled as "Sceptical occasional car sharers", constituting 7% of the sample. Of all clusters, members of this cluster have the lowest car sharing usage frequency. Furthermore, they are not motivated to use car sharing through environmental or utility-related aspects as they rate these indicators low compared to the other clusters. The low score on the statements related to the experienced effort it takes to use car sharing services indicates that members of this cluster experience more effort and are less satisfied with the service compared to the users in other clusters.

Together with the fifth cluster, members of this cluster are, on average, the youngest car sharers and further distinguish themselves by, on average, being car sharing members for the shortest period of all clusters (49 months). Besides, they are slightly less highly educated and live less

often in very highly urbanised areas than members of the other clusters. What further sets this cluster apart is that 62% of the members have either free on-street or private parking available to them. Therefore, it might not be surprising that car ownership is the highest in this cluster, with 32% owning at least one car. The higher car ownership might also explain the lower scores of these clusters on the utility and experienced effort related statements. Noticeable is that while car ownership is relatively high, the average number of disposed private cars is also the third highest of all clusters. This could indicate that members of this cluster have disposed of their second or third car since starting car sharing. Regarding the reported main car sharing trip purposes, groceries/shopping is reported more often compared to the other clusters, while a vacation or weekend trip is reported considerably less often. Lastly, as car sharing substitution mode, the private car is mostly chosen (32%) by the members of cluster six, while public transport is chosen less often (23%) than in all the other clusters.

5
Discussion of the results

This chapter elaborates on the results presented in the previous chapter by discussing them and comparing them to the findings of other studies on car sharing usage. First, the general findings on sample characteristics and the differences related to car sharing usage frequency groups are discussed. The second section provides an interpretation and discussion of the six identified clusters to put the results into perspective.

5.1. Discussion of variations associated with different membership lengths and usage frequency relations in the total sample

Before the Latent Class Cluster Analysis was conducted, the characteristics of three different groups with varying car sharing membership lengths were compared to explore if the characteristics of car sharers differed. From this comparison, it appeared that the characteristics of the new car sharers differed from those of long-term members. Particularly, differences were found regarding the education level and the residential density. Both aspects follow a similar pattern of decreasing levels of education and residential density among more recent members. However, only small differences were identified between the motivations of more recent and long-term members. These differences showed that long-term members are slightly more motivated through almost all motivations, except for the socially-related motives: 'the influence of others' and 'the joy of driving'. Besides these motives, more recent members showed lower car sharing use but greater intention to use shared cars more often than their long-term counterparts. Together with the fact that only around 10% of new members indicate that they will use car sharing less in the future, it can be concluded that most new members intend to remain car sharing members. Therefore, one might conclude that in light of the Diffusion of Innovation theory of Rogers (2003), the car sharing population is maturing as socio-demographic characteristics are changing.

However, while these differences were present, it should be acknowledged that for this analysis, only cross-sectional data were used. Therefore, it remains to be seen whether the socio-demographic differences between more recent and long-term members are caused by the diffusion of car sharing, or that they are related to car sharing membership length.

Considering the main car-sharing trip purpose and its relation with usage frequency, it appeared that with increasing car sharing use, more occasional purposes such as 'picking up and dropping off goods' decreased while more daily life activities such as 'sports/hobby/entertainment' increased. This aligns with the findings of Caulfield and Kehoe (2021), who found that frequent users were more likely to make shorter trips, while less frequent users were likelier to make longer trips. Compared to the findings of Becker et al. (2017) and Matowicki et al. (2021), it is noteworthy that 'visiting friend/family' was the main car sharing trip purpose in

this research, while they only found it to be the fourth most mentioned car sharing purpose for respectively station-based and zone-based users. However, Becker et al. (2017) identified 'visiting friends/family' as the most important trip purpose for free-floating car-sharing. This might be explained by the fact that free-floating car sharing is less widespread in the Netherlands, and its potential users currently use station-based car sharing. The other main trip purpose in this research, 'picking up and dropping off goods', was also one of the most important purposes in the study of Becker et al. (2017), which confirms the use of station-based car sharing for more occasional trip purposes.

The analysis on the substitution of car sharing trips showed that most respondents indicated they would have used public transport instead, followed by a private car. This would confirm the findings of Nijland and van Meerkerk (2017) on the substitution effect of car sharing trips in the Netherlands. However, as the car sharing usage intensified, the share of public transport decreased while the percentage of private car increased as the mode substitution. And when all responses were weighed, the private car substituted mainly car sharing trips instead of public transport. In addition, it should be noted that the public transport use of the car sharers in the sample was very high, which was also indicated by Becker et al. (2017). This suggests that car sharing is also complementary to public transport rather than solely competitive.

5.2. Interpretation and discussion of the identified cluster profiles

Interpretation of the indicators

This section will interpret the six identified cluster profiles and put the results into perspective by comparing them to other car sharing related studies. For clarity, first, an interpretation of the indicators is provided, followed by an interpretation of the covariates. From the cluster profiles listed in Table 4.5, it can be seen that the car sharing usage frequency differed but that the differences were rather small. This is also reflected in the average number of reservations of the clusters, which varies from 17.7 to 23.3. However, relatively larger differences between the clusters were visible when also considering the driven car sharing kilometres.

Reviewing the values of the environmental-related motivations, it became clear that large differences existed between the clusters. In general, the clusters with higher car sharing usage frequency showed higher values for environmental motivations. However, this did not hold for every cluster, such as for the fifth cluster, 'the environmentally-sceptical utility-focused car sharers', which had an average car sharing use but a very low score for environmental motivations. These large differences between the clusters show that not all car sharers have strong environmental motivations supporting their car sharing use and that generalisation of the car sharing population based on their environmental concerns is inappropriate. This is supported by findings of Ramos et al. (2020), who also found differences for three different groups of car sharers. Consequently, these differences between car sharers may clarify why some studies that considered the car sharing population as a whole found contradictory and sometimes ambiguous results regarding the influence of environmental concerns on car sharing intention and usage (Aguilera-García et al., 2022; Mattia et al., 2019; Münzel et al., 2019). Additionally, it is noteworthy that the clusters with the lowest values for environmental motives Were also, on average, the youngest groups. This suggests that younger people, to some extent, are not primarily motivated to use shared cars because they believe it contributes to a better environment.

Regarding the influence of the utility-related statements, the results show that for all clusters, these motives, and especially the cost motive, were important in people's consideration to use shared cars. This is in line with the previous studies, which found these motivations to be a good predictor of the intention to use car sharing services (Acheampong & Siiba, 2020; Curtale et al., 2021; D. Kim et al., 2015). Besides, it is interesting that moderately motivated car sharers (cluster 1) and sceptical car sharers (cluster 6), who have the lowest values for utility-related motivations, also have the highest car ownership of all clusters. This suggests that the experienced benefits of a shared car decrease when people own a private car, and could explain the often found negative influence of car ownership on car sharing membership and usage (Aguilera-García et al., 2022; Becker et al., 2017; Burghard & Dütschke, 2019; Ceccato & Diana, 2021). Lastly, not having to search for a parking spot was only considered an important motive for the utility-focused and highly conscious car sharers (cluster 2 and 4). Members of these clusters also resided more often in very densely urban areas with strict parking rules. This indicates that the certainty of a parking spot might only contribute to car sharing in highly urbanised areas with strict parking rules. The fact that the 'environmentally-sceptic utility-focused car sharers (cluster 5) did not perceive it as a benefit while living in similarly dense areas can be explained by their initial car-less lifestyle before using shared cars. While these results may suggest that having the certainty of a parking spot is not an important motive, it should be acknowledged that this may be caused by the fact that station-based car sharers are used to this certainty. This is supported by the finding that most respondents indicated that they preferred station-based car sharing over zone-based when asked about other types of car sharing (see Appendix D).

The cluster profiles also showed that the influence of others was not seen as an important motive to use car sharing and did not relate to a difference in usage frequency. This contradicts studies that found the social motive, including the influence of others, to be the most important predictor of the intention to (re-)use shared cars (Curtale et al., 2021; Mattia et al., 2019). As this study considered actual car sharing use, the disparity with studies on the intention to use car sharing suggests that the influence of others might contribute to the idea of using a shared car, but once someone becomes a member, it is no longer considered a motivating factor for using shared cars. Reviewing the values of 'the sharing of goods' as a motive for using car sharing, it is noticeable that the highest values were found for the environmentally motivated frequent car sharers (cluster 3) and highly conscious car sharers (cluster 4). This highlights the deliberate choice of these clusters to use shared cars as a replacement for their private car. For the sceptical clusters, it was found to be a less important motive. This highlights the fact that these clusters view shared cars more as a useful addition to their mobility options. Lastly, these cluster differences highlight the importance of acknowledging different motives between user groups. Should one have only considered the average cluster score for the sharing of goods, it could have been concluded that it was not an important motivation for all car sharers, as found by Aguilera-García et al. (2022), who found that the propensity to share goods positively influenced the adoption of car sharing but did not influence actual use.

Considering the statements related to the experienced effort, all clusters had relatively high scores on the ease of use and proximity to the shared car. This shows that, in general, station-based members were satisfied with the current service provided. Furthermore, it supports the positive influence of the expected effort on car sharing intention found by Curtale et al. (2021).

Considering the availability of the shared car, it is noticeable that this was experienced less positively in general and even negatively for the clusters with the lowest usage frequency. This extends the findings of Mattia et al. (2019), who found that the availability of free-floating shared cars is a limiting factor for the intention to re-use. Moreover, it addresses a trade-off for car sharing companies. Improving the availability of shared cars may increase its use, but it also increases the costs for the companies.

Another particularly interesting finding of this study is the importance of the motive for using shared cars because public transport is insufficient for those trips. First of all, it supports the study of Becker et al. (2017), who also identified it as an important reason to use shared cars for station-based and free-floating car sharers. Furthermore, it shows that shared car trips are not necessarily a competitor of public transport but also function as a complement to the mobility of people. The complement of shared cars to public transport was additionally supported by high public transport usage within the sample compared to the Dutch average (CBS, 2023c). However, across all clusters, station-based shared cars were generally not considered a last-mile solution for a train trip. This might be explained by the fact that Greenwheels offers round-trip car sharing instead of one-way, for which the potential to serve as a last-mile solution was argued (Shaheen & Chan, 2016).

Interpretation of the covariates

Looking at the socio-demographic characteristics of the cluster profile, some notable differences can be identified. First, the average age of all clusters is higher than in previous studies (Burkhardt & Millard-Ball, 2006; Ceccato & Diana, 2021). However, this could have been caused by an underrepresentation of younger members in the sample. Nonetheless, most clusters with a higher average age showed a higher usage frequency, which might suggest a positive relation between age and car sharing use. This differs from the literature, which suggests a negative influence of age on the adoption and usage frequency of shared cars (Aguilera-García et al., 2022; Prieto et al., 2017). A possible explanation of the positive relation might be that older users have incorporated using shared cars into their routines while younger members might use it occasionally when in need of a car. However, more specific research into these relations would be needed to test this explanation.

Regarding education and residential density, the cluster profiles are in line with previous studies on car sharing membership, as all clusters predominantly consisted of highly educated people residing in dense urban areas (Becker et al., 2017; Ceccato & Diana, 2021; Münzel et al., 2019). Consequently, no clear relation between education or residential density and the frequency of use was found, which aligns with the findings of (Aguilera-García et al., 2022). Lastly, it is noteworthy that the user group with the highest car sharing usage (the environmentally motivated frequent car sharers) also had the highest average household size (3.1). In this cluster, considerably more households with four members or more and fewer one-person households were present. This is particularly interesting as literature finds smaller households more likely to adopt car sharing services (Amirnazmiafshar & Diana, 2022; Ceccato & Diana, 2021; Prieto et al., 2017). Again, these findings highlight the importance of acknowledging that differences exist between car sharing users and that generalisation of those users is inappropriate. Furthermore, these findings could be valuable in light of expanding car sharing services by promoting them as a solution for (small) families.

Although car ownership was low among all clusters, the moderately motivated car sharers (cluster 1) and the sceptical car sharers (cluster 6) had relatively higher car ownership. These two clusters also showed the lowest car sharing usage frequency, supporting the negative impact of car ownership found in literature (Aguilera-García et al., 2022; Becker et al., 2017). However, when considering the change in car ownership, it is very interesting to note that the amount of car sharing use did not strongly relate to this change in ownership. It rather seems to be related to the initial car ownership before starting car sharing. Two different clusters exemplify this. The environmentally-sceptical utility-focused car sharers showed the lowest change in car ownership while having an average car sharing use, due to the initially low car ownership in this cluster. On the contrary, the sceptical car sharers showed the lowest car sharing use but the third highest change in car ownership. These results show important differences between the distinct user groups regarding the change in car ownership. However, on average, almost 30% of all members indicated that they disposed of at least one car, which suggests a strong positive impact of car sharing on car ownership. This is in line with many other conducted studies (Becker et al., 2018; Nijland & van Meerkerk, 2017; Oldenburger et al., 2019) and disapproves the more recent study of Bucsky and Juhász (2022), who argued that the impacts on car ownership found in user surveys were largely overestimated.

Additionally, this study was among the first to include the influence of different parking facilities available to car sharing users. While no clear relation between car sharing use and stricter parking regulations was found, significant correlations between car ownership and parking facilities and car ownership and car sharing usage frequency were identified (Chi-square tests can be found in Appendix D. As car sharing use did not seem to be strongly related to a change in car ownership, it would be interesting to further examine the influence of parking facilities and car sharing use on car ownership and the change in car ownership.

Between the cluster profiles, no major differences in trip purposes were notable except for environmentally motivated frequent car sharers and the sceptical car sharers, which were the user groups with the highest and lowest usage frequency. The environmentally motivated frequent car sharers had a considerably lower share of 'picking up and dropping off goods', which was to be expected based upon the general findings that higher usage frequency is associated with a lower share for this trip purpose. It also contributes to the suggestion that this user group uses shared cars as a complete replacement for a private car. The sceptical car sharers showed a very low share of 'vacation or weekend trip', which could be related to the higher car ownership in this cluster, reducing the need for a shared car in those situations.

Lastly, the results of clusters extend the findings of this study that higher car sharing usage in the sample is associated with a higher substitution of private car trips by identifying an additional influence of car ownership on the substitution effect. The clusters with the highest car ownership showed a relatively high percentage of private car substitution, while these clusters showed the lowest car sharing usage.

5.3. Key takeaways of the discussion

This study confirms several car sharing related findings of previous studies but also presents some key new insights on car sharing use. First of all, it finds that when weighed for use, car sharing substitutes mainly private car trips, instead of public transport trips, which are found

when considering unweighted results. Combined with the findings that insufficient public transport is one of the most important motives for using car sharing and the high levels of public transport use, this study shows that station-based car sharing is primarily complementary to public transport.

Furthermore, this study highlights that treating the station-based car sharing population as a homogeneous group is inappropriate and neglects individual differences and related impacts. For example, this study showed that a substantial group of larger households exists that deliberately chooses to use shared cars, and, in fact, use them the most of all identified groups in this study. Furthermore, this study shows that the reduction in car ownership depends more on the initial level of ownership rather than the amount of car sharing use. Another key finding is that while car use decreases for most users, this study shows that there is a particular group, the environmentally-sceptic utility-focused car sharers with low initial car ownership levels, for whom car use actually increases.

This study also finds disparities between factors influencing the intention to use car sharing and actual use. The main disparity is how 'the influence of others' is not regarded as an important motive for car sharing use, while studies on the intention to use found it to be one of the most important aspects.

6
Conclusion, Limitations & Recommendations

6.1. Conclusion

This study aimed to identify distinct station-based car sharing user groups to examine how different determinants of car sharing use vary among the identified groups. In light of growing environmental challenges, the need to reconsider how we approach personal transportation has become increasingly evident. Shared cars might prove essential in transitioning to a more sustainable and equitable transportation system that no longer prioritises private cars. The existing car sharing market, while promising, remains a niche market, which raises the question for both car sharing operators and governmental institutions on how to successfully increase sustainable transportation by means of the use of car sharing services. Moreover, the lack of comprehensive knowledge regarding the factors influencing the actual usage of station-based car sharing services, and particularly the tendency to treat car sharing users as a homogeneous group overlooking potential variations caused by individual differences, presented a research gap. As such, this study focused on revealing distinct usage profiles to gain a thorough understanding of car sharing usage. To do so, a comprehensive approach towards usage was adopted, including socio-demographic characteristics, spatial aspects, socio-psychological factors, and actual car sharing usage data. Data for this study was gathered by distributing a survey among members of the station-based car sharing company Greenwheels. A Latent Class Cluster Analysis (LCCA) was conducted to analyse the survey results.

The analysis identified the following six distinct station-based car sharing user groups: 1) *Moderately motivated car sharers*, 2) *Utility-focused car sharers*, 3) *Environmentally motivated active car sharers*, 4) *Highly conscious car sharers*, 5) *Environmentally-sceptic utility-focused car sharers*, 6) *Sceptical occasional car sharers*. This segmentation of station-based car sharers showed how these six groups differed in their motives for using car sharing and their related socio-demographic and spatial characteristics. Importantly, this segmentation highlights that there does not exist one specific type of car sharer and that implications of stimulating car sharing use may differ per group. Car sharing companies and policymakers should recognise these differences when designing strategies to promote car sharing use or enhance sustainable transportation.

For instance, analysis of the environmentally motivated frequent car sharers and the highly conscious car sharers suggests that they make a deliberate choice to use car sharing. These groups have the highest car sharing usage frequency and have the highest percentage of individuals who have disposed of a car (34% and 40%). Combined with the very low car ownership of both groups (90% and 95%) and the relatively high level of private car substitution for the car

sharing trip, this indicates that both groups use the shared car primarily as a replacement for private car use. Consequently, their impact on the reduction of private cars is quite substantial, but on total car use might be less.

On the contrary, the environmentally-sceptical utility-focused car sharers exhibit a lower impact on car ownership, explained by the fact that car ownership in this group was already low before they started car sharing. As a consequence, stimulating their car sharing use might lead to an increase in car use, which is supported by the fact that more people in this group indicated an increase in car use than a decrease after they started car sharing. This is not desirable from a sustainability point of view. However, as this is a relatively small group (7% of the sample), it can be argued from a societal point of view that enabling these individuals to access a car when needed enhances transportation equity.

The other utility focused group, which consists of 23% of the individuals, shows similarities with the environmentally-sceptical utility-focused car shares. However, members of this group are less sceptical in regard to environmental motives, and more individuals in this group disposed of a car as their initial car ownership was higher. Considering the travel behaviour of both groups, it is noticeable that they have the lowest shares of private car substitution for the car sharing trip (17% and 19%), combined with high levels of public transport substitution. This suggests that both clusters use the shared car as an addition to their mobility options rather than as a replacement for their private cars. Therefore, the total impact in terms of sustainability of these utility-focused groups is less positive.

Additionally, the sceptical occasional car sharers demonstrate one does not need to be motivated to use shared cars, other than the cost-benefit and perceiving public transport as insufficient, to dispose of private cars. Moreover, the relatively higher level of car ownership still present suggests that also second cars were disposed of, which differs from the other clusters. Furthermore, this cluster exemplifies that car sharing use does not need to be very high to cause a substantial change in car ownership. To a lesser degree, these findings also hold for the group of moderately motivated car sharers.

In conclusion, the results of the LCCA emphasise the importance of recognising diversity in underlying motives and implications associated with car sharing usage. To stimulate the beneficial impacts of car sharing and to enhance sustainable and equitable transportation, strategies should be tailored to these distinct user groups.

Besides the LCCA this study compared members with varying membership lengths to examine potential differences in their characteristics. From this comparison, it can be concluded that more recent members tend to have lower levels of education and reside in less densely urbanised areas compared to their long-term counterparts. Regarding the motives to use car sharing, new members are only slightly less motivated. Considering the use of shared cars, recent members show a lower usage frequency compared to long-term members. However, the future intention to use shared cars is significantly higher, as 25% of recent members indicate that they will use shared cars more often in the future. Furthermore, only 10% of the recent members indicate that they will use shared cars less often in the future, which suggest most of the newly attracted members will remain members.

Additionally, the descriptive results from the total sample provided several key insights. First of all, in line with earlier findings in the literature, the station-based car sharers primarily use the car for occasional trips. As the use intensifies, more routine-based trips are being made with the shared car. Furthermore, weighing the hypothetical mode substitution of car sharing trips for car sharing use showed that mostly private car trips are replaced. This differed from the unweighted results, where most individuals indicated they would have used public transport. In addition, it was found that as car sharing use intensifies, the substitution of private cars increases while public transport substitution decreases. Lastly, these findings, together with the high level of public transport use of station-based car sharers compared to the Dutch average, indicate that shared cars are mostly complementary to public transport rather than competitive.

6.2. Implications

This study contributes to the scientific body of knowledge on car sharing in multiple ways. First of all, by studying a large sample (N=1281) of actual car sharing members, this work combined survey data containing information about the motives of members with actual car sharing usage data. In addition, the comprehensive approach towards conceptualising car sharing usage resulted in a wide variety of factors that have been included in the analysis. Therefore, this study extends car sharing usage studies primarily focused on socio-demographic and spatial characteristics (Becker et al., 2017) or studies only considering actual usage data (Reiffer et al., 2019). This approach revealed that when both individuals' motives to use car sharing and the frequency of use of those individuals are considered, user groups primarily distinguish themselves in their motives. However, this does not mean that differences in car sharing use do not exist between users, but rather that more significant differences exist in the motives of users compared to the frequency of car sharing use.

Furthermore, using a Latent Class Cluster Analysis demonstrated that treating the car sharing population as a homogeneous group is incorrect. Instead, this study reveals the characteristics of the different user groups, each offering novel insights into the use and impact of car sharing. First of all, the different groups reveal that the impacts on car ownership and total car use are dependent on the type of car sharers and their underlying motives. This study has confirmed that station-based car sharing significantly reduces overall car ownership. On average, 30% of individuals have disposed of at least one car, which is consistent with previous studies (Nijland & van Meerkerk, 2017; Oldenburger et al., 2019; Schreier et al., 2018). However, more importantly, this study revealed that the reduction in car ownership varies depending on the type of user. For example, the impact of utility-focused car sharers, especially car-less individuals, is much lower compared to environmentally motivated and highly conscious car sharers.

In addition, the findings reveal that car sharing can have a positive effect on car ownership and usage even if there are not high levels of car sharing use. This implies that it may be more advantageous to attract new car sharers rather than trying to increase the usage of existing ones in order to decrease car ownership and usage.

Regarding the impact on car use, the environmentally-sceptical utility-focused cluster shows that car use can also increase because of car sharing, which might cause an increase in emissions of these individuals (María Arbeláez Vélez et al., 2021). However, as this is a relatively

small cluster, the previously mentioned equity benefits might outweigh the unwanted increase. As a side note, it should be mentioned that the engine type of shared car used or the total travel emissions of the user groups are not taken into account. Therefore the total impact on sustainability of the increase in car use remains unclear.

Analysing the different cluster profiles, some overall relations were identified, which should be studied in more depth to assess their actual impact. First of all, positive relations between the potential benefits of car sharing, the experienced effort to use shared cars and car sharing use are found. However, these relations might be associated with the level of car ownership and membership length. Clarifying these relations would be useful in regard to finding ways to decrease car ownership among users even more.

Secondly, different parking facilities showed a significant influence on belonging to a distinct user group and a significant influence on car ownership. However, from this study, it is not possible to determine whether strict parking facilities actually contributed to people's decision to start car sharing.

Lastly, this study revealed that a substantial group of users exists that come from households with on average three individuals. Interestingly, this group also showed the highest car sharing use, which suggests that car sharing is not just for smaller households. This demonstrates that families with more members might benefit from car sharing, even if they currently do not consider it an option. Additionally, it highlights the fact that other studies may have overlooked this specific group due to their focus on the average household size of the total car sharing population (Amirnazmiafshar & Diana, 2022; Prieto et al., 2017).

Another interesting finding resulted from considering actual car sharing use as opposed to the intention to use. This revealed that while the motive 'influence of others' is often found to be an important predictor of the intention to use car sharing, it was not found to be an essential motivation to actually use car sharing in this study (Curtale et al., 2021; Mattia et al., 2019). This suggests that the opinions of others are important when considering new ways of transportation, such as shared cars, but once a service is used, it is no longer regarded as an important aspect. The fact that younger car sharers were underrepresented in this study might have influenced this through the fact that younger individuals might value the opinions of others differently. Therefore, further research could explore this disparity by considering different age groups or different types of car sharing services, such as free-floating or zone-based.

This study also offers initial evidence that station-based car sharing in the Netherlands is diffusing and attracting a more diverse range of individuals. Looking back at the study's introduction, the recent increase in the number of car sharers suggests that car sharing may be expanding beyond its traditional niche. In conjunction with the discovery that car ownership reduction is not necessarily tied to the extent of car sharing use, this suggests that station-based car sharing could potentially have a substantial positive influence on car ownership levels in the future

An important consideration for these implications is that the study's respondents are still quite specific, residing mainly in highly urbanised areas, particularly in and around the Randstad, and they possess high levels of education. Therefore, it remains uncertain whether the iden-

tified user groups would remain consistent when a more diverse sample is considered. Furthermore, this means that the findings of this study may not be directly transferable to other regions or countries.

6.3. Limitations

Although this study provides new and interesting insights regarding station-based car sharing, it is important to address the limitations of this study.

First of all, the survey sample was found to be not fully representative of the total Greenwheels user group, as there was an underrepresentation of young people in the sample. The different motives and usage profiles of young people could have influenced the study. This holds specifically for the cluster analysis, as age significantly influenced cluster membership. A larger share of young car sharers might have elucidated the age differences across the identified clusters. Besides the underrepresentation of young people, there may be response bias, as those with a stronger opinion may be more inclined to fill out a customer research survey. In addition, participants could win driving credits for completing the survey, potentially incentivising rushed responses instead of thoughtful ones.

Regarding the aspects included in the survey, this study tried to include a comprehensive selection of aspects found to determine car sharing usage. Nonetheless, it is important to acknowledge that the motives and statements selected in this study, although based mainly upon aspects used in other studies, might not fully capture the attitudes and motives of the respondents.

Besides the selection of aspects to include, the way the latent class cluster model is designed influences the clustering outcome. For example, it was chosen to include car sharing usage as a categorical variable with five different levels instead of using the count of reservations. Including car sharing usage as the count of reservations would have resulted in larger usage differences between the clusters as the model finds more variation in the count of observations compared to the ranking of the motives. Consequently, the influence of most of the motives on cluster membership would become insignificant. As the aim of this study was not only to explore differences in car sharing usage but also to explore different motives for car sharing use, it was chosen to include car sharing usage as a categorical variable.

To analyse the impact of various motives and statements on cluster membership, each motivation and statement was considered as a separate indicator. However, as a consequence, many indicators were included, which resulted in a violation of the assumption of local independence as not all associations between the indicators are explained by the identified clusters. An example is the significant association between the motives ’cheaper than a private car’ and ’easier than a private car’ left in the final model.

Regarding the latent class cluster model, it was assumed that the variable ’experience with car sharing’, which was measured by the membership length of the car sharer, was not influenced by any of the indicators. However, it might have been possible that the experienced effort to use shared cars influenced the membership length, as more satisfied users might have longer memberships.

Another limitation of this study is the absence of a control group to compare the results. Due to resource and time limitations, only one group of station-based car sharers was included. Including station-based car sharers of different companies or even other types of car sharing, such as zone-based or free-floating, would have put the results into a broader perspective.

6.4. Recommendations

The results of this study can provide helpful guidance for car sharing companies and governmental institutions. As car sharing companies in the Netherlands are private companies, their motives for increasing car sharing use differ from those of governmental institutions. However, this does not mean that car sharing companies cannot contribute to the goals of governments by providing a good service which has a beneficial impact on the liveability of cities. The companies offering car sharing services provide the actual service, while the governmental institutions can shape the landscape and conditions for these services. In addition, some recommendations for future research can be made based on the findings of this study. The following subsections will explain the recommendations resulting from this study.

Recommendations for future research

First of all, this study identified distinct user groups and touched upon the impact of these different groups on car ownership and use. However, from a sustainability point of view, it would be valuable to study the impact of car sharing use of these distinct user groups on the environment in more detail. By including also the daily travel habits, such as the usage of other modes or distances travelled, more insights into the total sustainability impact of the different car sharing groups are gained.

In addition, future research could focus on examining the relations between stricter parking policies, the decision to become a car sharer and car ownership. Clarifying these relations would provide valuable knowledge on the role of car sharing in reducing car ownership. To do so, a study could consider estimating the impact of introducing stricter parking facilities alongside the introduction of car sharing services in that same area. That way, real impacts could measured by, for example, conducting two-wave surveys.

As stated in the limitations, it would be useful to extend this study by replicating it with a different group of car-sharing members, such as members from other companies and other types of car sharing systems. Putting these results into perspective could reveal if similar user groups with related motives exist among zone-based and free-floating car sharers. In addition, as car sharing might be diffusing towards less urbanised areas, it could be explored how residents in less urbanised areas use the system and if different usage profiles are identified, which might ask for a different car sharing service.

More in-depth research into the diffusion of car sharing could contribute to verifying if, indeed, a different part of the population is attracted to car sharing. This would help to determine the potential of car sharing in the near future and if it can step outside of the niche. To do so, instead of cross-sectional data used in this study, longitudinal data about car sharing members are required. The use of longitudinal data would also enable assessing how motives might change over time and whether this has an influence on the identified user groups in this study.

Lastly, as stated in the limitations, this study included all motives as separate indicators, resulting in significant correlations of some indicators. Future studies could consider using factor analysis to reduce the number of correlated indicators. This could prevent biases in cluster probabilities, leading to a better and more parsimonious model. Moreover, the estimated model might be easier to interpret due to the reduced number of indicators. This increased interpretability of the results could enhance communicating its outcome beyond academia.

Recommendations for governmental institutions

Considering the desire to reduce car ownership in urban areas, governmental institutions should focus on increasing the number of car sharers rather than increasing the frequency of car sharing use. This is supported by the fact that the impact on car ownership reduction is substantial for all users, even for more sceptical and occasional users. In addition, it might be more effective to focus on areas with higher levels of car ownership, as addressing groups with already low car ownership might cause an increase in car use.

From an equity perspective, governments could support car sharing services for formerly carless individuals. While this might not be beneficial in terms of total car use, offering car sharing to these individuals could contribute to a more equitable transportation system. Offering car sharing services to these individuals might be less attractive to car sharing companies because it most likely concerns individuals who will not use car sharing services very often. Therefore, governments could consider subsidising car sharing or thinking of ways to offer shared cars as a type of public transportation.

Building on the relationship between public transport and shared cars, governmental institutions could explore ways to promote the interaction between shared cars and public transport. As all users indicate that they use shared cars when public transport is perceived as insufficient, it can be deduced that shared cars are currently a necessary supplement to public transport for carless individuals. Therefore, governments could even think of ways to use shared cars as a means of public transportation, making them more accessible and even further reducing the need for private cars. This would specifically apply to public transport travellers who still own a car for occasional trips.

Lastly, as transporting goods is an important motivation to use station-based car sharing, municipalities of very dense urban areas with very scarce public space could explore the possibility of promoting shared cargo bikes alongside shared cars. Using these shared cargo bikes for transporting goods over relatively short distances in inner cities could potentially reduce traffic even more than shared cars.

Recommendations for car sharing companies

First of all, car sharing companies could exploit the identified user groups of this study. They could do so by advertising the specific strengths and benefits of car sharing to the different (potential) user groups. For example, for utility-focused groups the perceived benefits in terms of convenience, costs and having an extra transportation option should be promoted while for the environmental and highly conscious car sharers the sustainable image should be highlighted. To the moderately motivated and sceptical car sharers, the possibility of disposing of a second car and the added value of a shared car as an additional travel option could specifically be promoted.

Secondly, car sharing companies should consider targeting individuals with low levels of private car use specifically by promoting the cost-benefits of car sharing. This is supported by the fact that 'cheaper than a private car' is considered the most important motivation for all groups. In addition, calculations have shown that car sharing can be cheaper than owning a car if an individual drives less than 10.000 kilometres per year, while the people in the Netherlands drive an average of around 11.000 kilometres per year (CBS, 2022a). Therefore, it might be the case that a large group of potential users is not fully aware of the potential cost benefits related to car sharing. While car sharing companies are already doing this,

Furthermore, car sharing companies should consider increasing the number of shared cars to improve availability, as this is an aspect found insufficient by lower usage groups. The cluster analysis results show that the two clusters with the lowest use most often find the availability of the shared car insufficient. This suggests that car sharing usage could be increased if the supply of shared cars increases.

Lastly, car sharing companies could consider attracting more members via (free) trial as there might be a hurdle for people to start using car sharing. This recommendation is built on the fact that all groups rate the experienced benefits related to car sharing positively. Furthermore, as they seem to increase with longer membership length, car sharing companies should try to keep those members involved for a while for them to perceive the benefits even more.

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A
Scientific Paper

Driving factors behind station-based car sharing use in the Netherlands
Discovering distinct user profiles through a Latent Class Cluster Analysis

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Abstract
In light of growing environmental challenges, the need to reconsider how we approach personal transportation is becoming increasingly evident. A shift from a private car-focused mobility system towards a more sustainable and equitable transportation system is desired. Car sharing is considered a means to achieve this. However, car sharing use and its related impact are not entirely understood, as many studies do not consider the car sharing motives of individuals and treat the car sharing population as a homogeneous group. This study aims to reveal distinct car sharing usage profiles to gain a thorough understanding of car sharing utilisation and its related impact. Six distinct user profiles are uncovered using a Latent Class Cluster Analysis (LCCA) based on station-based car sharer data gathered through an online survey (N=1281). This segmentation underscores the diversity in car sharing motives and reveals that the impacts associated with car sharing use differ across the identified user groups. The cluster profiles show that environmentally motivated car sharers use the shared car as a complete replacement for their private car, causing a substantial decrease in car ownership and use. More utility-focused car sharers, and especially initially carless individuals, show a less substantial decrease in car ownership and sometimes even an increase in car use. This study concludes with recommendations based on these findings and discusses its limitations.

Keywords: *Car sharing, latent class cluster analysis, motives, travel behaviour*

1. Introduction

In light of growing environmental challenges, the need to reconsider how we approach personal transportation is becoming increasingly evident. Private cars take up 55% of the available public street space in the 20 largest Dutch municipalities while, on average, they remain parked 96% of the time (Jorritsma et al., 2021; van Liere et al., 2017). In addition, with many countries facing challenging sustainability goals and increasing issues regarding the livability of cities, governments and institutions are acknowledging the need to shift from a private car-focused mobility system towards a more sustainable and equitable transportation system (Greendeals, n.d.). However, unlike many other Western countries, car ownership in the Netherlands has not exhibited a decreasing trend in recent years (Kroesen & van Wee, 2021). Therefore, shared cars might play an important role in this transition as their utilisation is often associated with a decrease in car ownership and use (Kolleck et al., 2021; Nijland & van Meerkerk, 2017). In addition, the use of shared cars is associated with a modal shift away from private cars towards more sustainable (active) modes (Becker et al., 2017). However, these positive influences are debated as some studies find smaller on even negative influences of car sharing use (Bucsky & Juhász, 2022; María Arbeláez Vélez et al., 2021; Nijland & van Meerkerk, 2017; Papu Carrone et al., 2020). Besides the influence on environmentally related aspects, car sharing may increase transportation equity as it enables formerly carless households to use car when they need to (Shaheen et al., 2020).

As car sharing services have permanently been around for over 30 years, many car sharing related studies have been conducted (Ferrero et al., 2018). A considerable amount of studies have focused on socio-demographic factors that influence the adoption and use of car sharing services. This resulted in a typical car sharer profile of someone who most likely is a male, is young, is highly educated and resides in dense urbanised area, in a small household with low car ownership (Aguilera-García et al., 2022; Becker et al., 2017; Burghard & Dütschke, 2019; Ceccato & Diana, 2021; Hjorteset & Böcker, 2020; Prieto et al., 2017). However, most studies did not consider psychological aspects such as individuals' motives for car sharing use (Ramos et al., 2020). This neglects the influence of personal motives on car sharing use and may result in an overestimation of the influence of socio-demographic factors.

From studies that did consider personal motives for car sharing, three main categories of motives were identified: environmental-, costs- and utility-related motives (Mavlutova et al., 2021). However, the influence of these motives, and especially the environmentally related motives, seems to differ between conducted studies (Aguilera-García et al., 2022; Mattia et al., 2019; Münzel et al., 2019). While these differences might be attributed to the different study areas and data used, it is also notable that these studies treat the car sharing population as one homogeneous group, neglecting potential variations caused by individual differences. Moreover, this generalisation of the car sharing population overlooks the fact that varying motives for using car sharing may have different impacts on individuals' travel behaviour, which may lead to varying car sharing impacts.

As illustrated, studies on car sharing use and its related impact provide contradictory results and overlook the influence of individual differences of car sharers. Because of the generalisation of the car sharing population and its related impacts, it remains difficult to develop effective car sharing strategies that stimulate sustainable travel behaviour and a decrease in car ownership. Therefore, this study focused on revealing distinct car sharing usage profiles to gain a thorough understanding of car sharing utilisation and its impact in terms of sustainability. To do so, a comprehensive approach towards usage has been adopted, including socio-demographic characteristics, spatial aspects, socio-psychological factors such as motives, and actual car sharing usage data. These data were gathered through a collaboration with the station-based car sharing company Greenwheels, which distributed an online survey among its members.

2. Methodology

Conceptual model & data gathering

To determine the factors that influence car sharing use, a literature review was conducted. This resulted in an overview of factors influencing car sharing adoption and usage, which can be found in Table 1. By combining the findings of the literature study with behavioural theories such as the theory of planned behaviour (TPB) and the UTAUT2 model, a conceptual model for distinguishing distinct user profiles was constructed (Ajzen, 1991; Venkatesh et al., 2012). The conceptual model used in this study can be found in Figure 1.

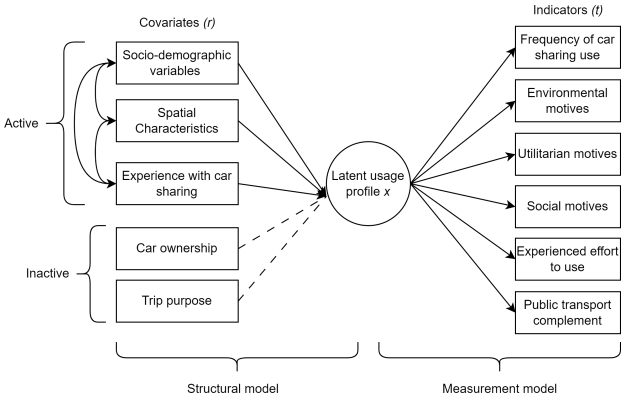

Figure 1: Conceptual model for car sharing use

The model shows that different latent usage profiles, which represent the identified user groups, are based on a set of chosen indicators and covariates. For the indicators, individuals' actual car sharing use and their different motives for using car sharing are chosen. On the left-hand side of the model, the covariates are displayed that are assumed to influence belonging to a specific user group. Considering causality, it makes sense to incorporate individuals' motives and car sharing use as indicators. This way, the model conceptually assumes that personal motivations to use car sharing and the amount of car sharing use are influenced by the covariates and not the other way around.

Regarding the indicators, the most important types of motives for using car sharing identified in the literature are included. These are the utilitarian, environmental and social motives and the experienced effort to use shared cars. The utilitarian motives capture how different perceived benefits motivate car sharing use. The environmental motives capture to what extent car sharing use is motivated by the individuals' belief that car sharing contributes to a better environment. Social motives are included to capture the influence of subjective norms, such as the opinion of others on an individual's choice to use shared cars, and the hedonic motivations to use shared cars, such as experiencing driving as fun or having a preference for sharing goods. The experienced effort to use shared cars is included to capture to what extent individuals feel they need to make an effort to use shared and if they are satisfied with the service. In

Table 1: Factors influencing car sharing adoption and use

Factor	Study
Socio-demographic	
Age	Aguilera-García et al. (2022), Becker et al. (2017), Burkhardt and Millard-Ball (2006), and Kim et al. (2015)
Gender (male)	Aguilera-García et al. (2022), Becker et al. (2017), Hjorteset and Böcker (2020), Kim et al. (2015), and Prieto et al. (2017)
Education level	Acheampong and Siiba (2020), Ceccato and Diana (2021), Millard-Ball et al. (2005), and Münzel et al. (2019)
Income	Aguilera-García et al. (2022), Clewlow (2016), and Münzel et al. (2019)
Household size	Ceccato and Diana (2021) and Prieto et al. (2017)
Occupation	Aguilera-García et al. (2022), Becker et al. (2017), and Hjorteset and Böcker (2020)
Car sharing service related	
Car sharing costs	Papu Carrone et al. (2020) and Wang et al. (2021)
Proximity of shared car	Schreier et al. (2018) and Wang et al. (2021)
Availability of shared car	Mattia et al. (2019)
Spatial characteristics	
Residential density	Prieto et al. (2017) and Wang et al. (2021)
Private parking	Ceccato and Diana (2021)
Socio-psychological aspects	
Environmental concerns	Becker et al. (2017), Mattia et al. (2019), Ramos et al. (2020), and Schaefers (2013) Aguilera-García et al. (2022) and Münzel et al. (2019)
Utilitarian motives	Curtale et al. (2021), Mavlutova et al. (2021), and Münzel et al. (2019)
Subjective norms	Curtale et al. (2021) and Kim et al. (2015)
Hedonic Motivation	Aguilera-García et al. (2022)
Effort expectancy	Curtale et al. (2021) and Mattia et al. (2019)
Other	
Car ownership	Becker et al. (2017), Burghard and Dütschke (2019), and Hjorteset and Böcker (2020) Aguilera-García et al. (2022) and Ceccato and Diana (2021)
Public transport subscription	Becker et al. (2017) and Münzel et al. (2019)
Trip purpose	Becker et al. (2017) and Matowicki et al. (2021)
Prior experience	Venkatesh et al. (2012)

addition to these motives that were identified in the literature, motives that account for the interaction between shared cars and public transport are included. Lastly, the actual car sharing frequency of an individual is included as an indicator.

To obtain measures for the indicators, the respondents' attitudes on various statements related to included motives are asked. All attitudes of the respondents are measured on a 5-point Likert scale. The car sharing frequency of the individuals is based on the number of reservations made from July 2022 to July 2023. Table 2 presents the 16 different indicators.

Regarding the covariates, because it was not desired to include questions regarding income, gender and occupation in the survey, these characteristics are excluded. The remaining socio-demographic characteristics are age, education level and household size. Furthermore, two spatial characteristics are included as covariates, which are residential density and parking facilities available. Lastly, trip purpose, car ownership and experience with car sharing are included as covariates. Experience with car sharing is included based on its presence in the UTAUT2 model and because its influence on car sharing usage has yet to be studied extensively. Including trip purpose reflects that individuals may vary in their car sharing use and motives for use based on their car sharing travel purposes.

In order to avoid endogeneity issues, where a covariate is dependent on the variable it is trying to predict, both car ownership and car sharing trip purpose are included as inactive covariates. This is because both factors may be influenced by indicators as the frequency of car sharing use or some motivations.

Data were gathered through the distribution of a survey among members of the station-based car sharing company Greenwheels. The survey was sent to 13573 members between the 4th and 16th of July 2023, and in total, 1393 responses were gathered, resulting in a response rate of 10.3%. After preparing the data by removing incomplete and invalid responses, 1281 valid responses remained. Besides an underrepresentation of young respondents and a slight overrepresentation of single-person households, the sample can be considered a good representation of Greenwheels members.

Latent Class Cluster Analysis

The next step is to perform a Latent Class Cluster Analysis (LCCA). LCCA is a model-based probabilistic clustering method aimed at revealing groups, in this case station-based car sharers, that are similar

Table 2: Measurements of indicators

Indicators
Environmental motives
I use shared cars because they have lower emission compared to private cars
I use shared cars because by doing so, I contribute to the reduction of traffic in my city
I use shared cars because it contributes to creating extra space for other/enjoyable things in my city
Utilitarian motives
I use shared cars because it enables me to save money compared to owning a private car
I use shared cars because it is easier than owning a private car
I use shared cars because it improves the quality of my trip compared to the mode of transport I would have used otherwise
I use shared cars because it means I do not have to look for a parking place for my car
Social motives
People around me encourage me to use shared cars
I use shared cars because I enjoy driving in a car
I use car sharing services because sharing goods with others appeals to me
Experienced effort to use car sharing
I find it easy to use car sharing services
I am satisfied with the distance from my house to the shared cars I use
Shared cars are not always available when I intend to use them
Public transport complement
I use shared cars to travel from a train station to my final destination
I use car sharing for trips where public transport is insufficient
Frequency of car sharing use 5) >52 reservations (weekly or more often) 4) 25-52 reservations (2-4 times per month) 3) 12-24 reservations (1-2 times per month) 2) 6-11 reservations (6-11 times per year) 1) 1-5 reservations (1-5 times per year)

based on observed characteristics (Kroesen, 2021). The main theoretical idea of LCCA is that an underlying discrete latent class variable accounts for the correlations between a set of indicators(Molin et al., 2016). It does so that, conditional on that latent class variable, the correlations between those indicators become insignificant (Magidson & Vermunt, 2004). The goal is to find to model with the smallest number of clusters that maximises the homogeneity within the clusters and heterogeneity between the clusters (Molin et al., 2016). Unlike traditional deterministic clustering methods, such as K-means clustering, LCCA is a probabilistic clustering method. This means that individuals are assigned to different clusters with a certain probability of belonging to that cluster, rather than deterministic, i.e. with a probability of one, to different clusters (Kroesen, 2021). Consequently, this is also one of the main advantages of LLCA compared to traditional deterministic clustering methods because it prevents biases in cluster centres due to the deterministic assignment of individuals to the different cluster centres (Magidson & Vermunt, 2002). Other advantages of LCCA are that it can handle variables of different scale types (nominal, ordinal, continuous and count) and that statistical criteria are available to determine the optimal number of classes (Magidson & Vermunt, 2002).

The LCCA conducted in this study consists of two parts: 1) the estimation of the measurements model to determine the optimal number of classes and 2) the extension of the measurement model with a structural model by adding covariates to the model that influence an individual's cluster membership. To perform the LCCA the software package LatentGOLD®5.1 was used (Vermunt & Magidson, 2016). Commonly used statistical criteria to determine the optimal number of classes are the likelihood-ratio chi-square statistic L^2, the Bayesian Information Criteria (BIC), Akaike's Information Criteria (AIC) and the Bivariate Residuals (BVR) (Magidson & Vermunt, 2004). The likelihood-ratio chi-squared statistic assesses to what extent the expected cell frequencies differ from the observed cell frequencies, with the null hypothesis that the difference is zero and, thus, no relationship exists in the population. However, in the case of sparse data, the chi-squared distribution should not be used to determine the p-value for the L^2 (Magid-

son & Vermunt, 2004; Molin et al., 2016). Since the estimated model included 16 variables, of which each had 5 categories, there were 5^{16} possible response patterns, and thus many cells remained empty. Therefore the BIC and AIC were used, which are global modal fit criteria based on the likelihood function. For both criteria, the cluster with the lowest value is unusually preferred. Additionally, the BVR is a local model fit criterion that shows the existing correlation between the indicators in the model. At a significance level of 5%, BVR values lower than 3.84 are preferred (Molin et al., 2016). Besides these statistical criteria, the theoretical interpretability of the clusters was taken into consideration to determine the number of clusters. To ensure interpretability, usually cluster sizes of at least 5% are desired (Weller et al., 2020).

After the optimal number of clusters was determined, the model was extended with a structural part by adding the covariates. To determine whether or not to include a covariate in the model, their significance was tested with the Wald-statistic (Vermunt & Magidson, 2016). Covariates with a Wald-statistic p-value < 0.05 indicate statistical significance and thus were included in the model as active covariates. Non-significant covariates, however, could still be included in the model as inactive covariates. Inactive covariates do not influence class membership but can provide information about the distribution of that covariate within a cluster (Molin et al., 2016). To avoid any issues of endogeneity, car ownership and trip purpose were included as inactive covariates.

3. Results

First, the measurement model with only the indicators was estimated to determine the optimal number of clusters. In Table 3, it can be seen that the AIC-value continued to decrease when the number of clusters increased, indicating a 10-cluster model would be statistically optimal. However, the lowest BIC value was found for the 7-cluster model. Taking the BVR-values into consideration did not provide additional support for a specific number of clusters since large BVR-values (>3.84) were present in all models. The smallest cluster size for the 7-cluster model was 2.3%, thus violating the rule of thumb of 5%. As the 6-cluster model proved to have sufficiently big cluster sizes and provided meaningful clusters for the interpretation, this model was selected.

To extend the measurement model with a structural model, all initially selected active covariates present in Figure 1 were added. Two covariates, education level and residential density, showed a p-value > 0.05 based on the Wald-statistic. The variable with the largest p-value, education level, was made inactive and, therefore, no longer influenced class-membership. Consequently, the model was re-estimated with the remaining covariates. As residential density remained insignificant, with a p-value of 0.44, it was also made inactive. After re-estimating the model again, all covariates had a significant p-value, indicating that they significantly influence class-membership.. Lastly, the entropy R^2 of the total model was checked to assess to what extent the model accurately assigned the individual cases to the six clusters. The final latent class cluster model had an entropy R^2 of 0.77, which was slightly lower than the desired 0.80 but still sufficient. In addition, the standard R^2 for the covariates was 0.05, indicating that only a small portion of the variability in class membership was explained by the included covariates.

Table 3: Model fit statistics for different numbers of clusters

No. of clusters	Npar	LL	BIC(LL)	AIC(LL)	Max BVR	Smallest cluster
1	64	-27986.2	56430.4	56100.5	805.5	100.0 %
2	81	-27240.2	55060.0	54642.4	199.4	39.6%
3	98	-26899.0	54499.2	53993.9	141.8	15.2%
4	115	-26719.7	54262.3	53669.4	82.7	13.9%
5	132	-26580.0	54104.5	53424.0	52.4	7.4%
6	149	-26483.5	54033.1	53264.9	47.4	**6.6%**
7	166	-26406.8	**54001.3**	53145.5	45.1	2.4%
8	183	-26356.6	54022.6	53079.1	41.3	2.2%
9	200	-26307.2	54045.6	53014.5	45.1	2.2%
10	217	-26257.1	54067.0	**52948.3**	41.4	2.1%

The final model, including the indicators and covariates, is presented in Table 4. Several additional variables are included as inactive covariates that were not present in the conceptual model as they provide additional information and context for the identified clusters. These variables are the number of disposed cars after starting car sharing, car sharing trip substitution and the driven car sharing kilometres. A description of the six distinct clusters can be found below.

Cluster 1: Moderately motivated car sharers

Members of this cluster are identified as 'Moderately motivated car sharers' as they do not distinguish themselves from the other clusters through specific high or low scores on the indicators. Regarding the environmental motives for using car sharing, the members of this cluster are rather indifferent and do neither agree nor fully disagree with the statements.

Table 4: Within cluster distribution of indicators and covariates for the 6-cluster model

	Cl.1	Cl.2	Cl.3	Cl.4	Cl.5	Cl.6	Sample
Cluster size	32%	23%	19%	12%	7%	7%	
Indicators (mean)							
Usage frequency	2.52	2.62	2.79	2.62	2.55	2.29	2.59
Environmental motives							
Reduce emissions	2.97	3.20	3.98	4.15	1.50	1.55	3.15
Reduce traffic	3.34	3.78	4.55	4.95	1.40	1.41	3.59
Create public space	2.99	3.24	3.95	4.68	1.32	1.32	3.20
Utility motives							
Cheaper than a private car	4.19	4.88	4.26	4.85	4.85	3.81	4.46
Easier than a private car	3.67	4.73	3.80	4.92	4.62	2.73	4.09
Improves trip quality	3.41	3.91	3.50	4.14	4.17	2.88	3.65
No parking search	2.81	3.49	2.94	4.15	2.81	1.68	3.07
Social motives							
Influence of others	2.77	3.20	2.80	3.71	2.80	2.01	2.94
Joy of driving	2.77	2.85	2.65	3.03	2.71	2.55	2.78
Sharing of goods	3.25	3.69	4.16	4.41	2.80	2.37	3.57
Experienced effort to use							
Use is easy	3.87	4.72	4.34	4.82	4.64	3.67	4.31
Proximity to shared car	4.05	4.98	4.59	4.92	4.91	3.83	4.51
Shared car not available	3.23	2.13	2.84	2.46	2.22	3.24	2.74
Public transport motives							
As last-mile solution for a train trip	2.04	2.02	2.35	2.41	1.66	1.50	2.08
Instead of insufficient PT	4.27	4.52	4.59	4.75	4.44	3.95	4.44
Active covariates							
Age *(mean)*	50	54	53	57	48	48	52
Membership length in months *(mean)*	66	99	96	99	89	49	83
Household size *(%)*							
1	27	36	19	29	33	32	29
2	40	45	42	44	40	37	42
3	15	12	12	11	12	14	13
4+	18	7	27	15	16	17	17
Mean	2.3	1.9	3.1	2.2	2.3	2.2	2.3
Parking facility available *(%)*							
Paid/permit on-street parking	50	74	52	78	71	38	60
Free on-street parking	33	17	26	18	15	32	25
Private parking spot	16	8	21	5	11	30	14
Other	1	2	1	0	2	0	1
Inactive covariates							
Car ownership *(%)*							
0	80	92	90	95	89	68	86
1	19	7	10	5	11	28	13
2+	1	1	1	1	0	3	1

Car disposed after car sharing *(%)*							
0	74	73	66	59	85	70	71
1	26	26	33	40	13	27	28
2 or more	0	1	1	1	1	3	1
Education *(%)*							
None/primary education	0	0	1	1	0	0	0
Secondary education/MBO1	7	7	5	5	8	8	6
MBO2-4	5	6	5	6	5	5	5
HBO/WO	82	84	86	85	87	79	84
I would rather not say	6	3	3	3	0	8	4
Residential Density *(%)*							
Very highly urban	67	85	73	85	86	66	76
Highly urban	25	11	19	11	9	23	18
Moderately urban	4	3	5	4	3	9	4
Little urban	2	1	2	0	2	0	1
Non-urban	1	0	0	0	0	2	1
Main car sharing trip purposes (*% answered yes*)							
Groceries/shopping	22	23	16	15	20	28	21
Visiting friends/family	61	67	70	72	72	60	66
Sports/hobby/entertainment	19	15	20	17	24	19	18
Vacation or weekend trip	32	28	30	33	20	11	25
Going from and to work or study	14	10	15	11	15	14	13
Picking-up/dropping-off goods	55	58	30	56	54	50	56
(Health)care	4	5	3	6	4	4	4
Other	5	5	5	4	5	10	6
Car sharing trip substitution *(%)*							
Shared car from other company	8	10	8	8	8	10	9
Car from family/friend/acquaintance	11	8	10	7	8	12	10
Private car	25	19	31	24	17	32	25
Ride along with someone else	8	9	5	10	9	9	8
Public Transport	33	40	36	41	49	23	36
(E-)bike	7	5	3	5	2	8	5
I would not have made the trip	5	5	5	1	5	3	4
Other	3	4	2	3	1	3	3
Car use after car sharing *(%)*							
More	28	31	23	20	45	19	27
Equal	34	30	35	34	34	46	34
Less	38	40	42	46	21	35	39
Car sharing kilometres *(mean)*	877	940	1270	1146	1018	703	996
Number of reservations *(mean)*	18.8	20.5	23.3	22.6	20.4	17.7	20.6

While the members of this cluster rate the utility-related statements slightly positive, their scores are rather low compared to the other clusters. The same applies to the statements related to the experienced effort to use shared cars.

With an average membership length of 66 months, members of this cluster are car sharing members for a shorter period than most other clusters. Besides this, the first cluster has the second highest car ownership, with 20% of its members owning at least one car. Compared to the other clusters, members of cluster one reside less in very highly urban areas and more often in highly urban areas. Regarding the main car sharing trip purposes, members of this cluster use the shared car more often for a vacation or weekend trip compared to the other clusters. In addition, while still being the most reported trip purpose, visiting friends or family is reported relatively less often within this cluster.

Cluster 2: Utility-focused car sharers

Members of this cluster rate the utility-related motives to use shared cars high and, in particular, the cost-related motive, which has the highest score of all clusters. In comparison to the other clusters, this cluster scores average on the three statements about the environment. Interesting to note is the very positive scores on the statements related to the experienced effort it takes to use shared cars. Furthermore, the members in the cluster are characterised by a long average car sharing membership duration (99 months) and by having the lowest average household size (1.9). The parking facilities available to the members of this cluster are predominantly paid or permit on-street parking (74%). Therefore, it might not be surprising that within this cluster 92% does not own a private car. Combined with the below-average percentage of people who disposed of cars, this indicates that most members of this cluster did not own a car before they started car sharing. This may also explain the relatively low share of car substitution (19%) compared to the other clusters. It can be inferred that car sharing is used as an addition to their initial public transport oriented travel behaviour.

Cluster 3: Environmentally motivated frequent car sharers

Members of the third cluster show the highest car sharing use of all clusters. Furthermore, this cluster distinguishes itself from the other clusters by scoring high on environmentally-related motives while scoring relatively lower on utility-related motives. This indicates that members of this cluster make a conscious choice, based on their attitudes related to the environment, to use shared cars. In addition, the low score on the joy of driving and the high score on the preference for sharing goods could support this.

The members in this cluster typically live in the largest households of the sample with an average size of 3.1 individuals. Furthermore, they have the highest car sharing use and relatively fewer members live in very highly urban areas (73%). It is worth mentioning that while members of this cluster have an above-average share of free on-street (26%) and private parking facilities (21%) available to them, car ownership within this cluster is very low (90% do not own a car). 34% of the members in this cluster have disposed of at least one private car since they started using Greenwheels, and they show a high car sharing trip substitution for the private car (31%). This indicates that members of this cluster use the shared car as a full replacement for a private car they would have used otherwise. This is also supported by the fact that members of this cluster use the shared car substantially less for occasional trips such as 'picking up or dropping off' goods.

Cluster 4: Highly conscious car sharers

The highly conscious car sharers make a very deliberate and motivated choice to use shared cars. This is exemplified by their high scores on all environmental- and utility-related statements. This cluster distinguishes itself from the third cluster by the high values on the utility-related motives. Furthermore, members of this group have the highest score on the statement related to the sharing of goods, which supports the suggestion that they make a deliberate choice to use shared cars.

Members of this cluster are characterised by being the oldest of all clusters with an average age of 57, and together with the second clusters, they are on average Greenwheels members for the longest period (99 months). At the residences of members within this cluster, 78% have paid or permit on-street parking available to them, which is the highest percentage of all clusters. This may explain the fact that this cluster has the highest score on the indicator related to not having to search for a parking spot when using a (station-based) shared car. Furthermore, car own-

ership within the cluster is the lowest of all clusters, with only 6% owning a car. In addition, 41% of the members have disposed of at least one car after they start using car sharing, which is the highest percentage of all clusters. This highlights that, similar to the third cluster, members of this cluster have made a deliberate choice to replace their private cars by using shared cars.

Cluster 5: Environmentally-sceptical utility-focus car sharers

For the members of this cluster, the environmentally related statements are no motivation at all to use car sharing. However, the utility-related statements, except for not needing to search for a parking spot, are rated high by the members of this cluster. Compared to the other clusters, the members of this cluster do not like the idea of sharing goods as much. Reviewing all the scores on the indicators of this cluster suggests that its members mainly use the shared car because it benefits them in terms of money, effort and trip quality.

Together with the sixth cluster, the members of this cluster are, on average, the youngest of all (48 years). However, different from cluster six, members of this cluster are, on average, car sharing members for a longer period (89 months compared to 49). When reviewing the level of car ownership, it is noticeable that while car ownership is low, the amount of disposed cars after starting using car sharing is the lowest of all clusters (14%). This shows that car ownership in this group was already low before using car sharing. Therefore it is unsurprising that 49% of this cluster indicates that they would have used public transport if they could not have used a Greenwheels shared car and that only 17% of this cluster indicates that they would have used a private car if they could not have used a Greenwheels shared car, which is the lowest of all clusters. Altogether, this suggests that members of this cluster were initially car-less individuals and that car sharing enabled them to use a car. This suggestion is also supported by the fact that this cluster is the only cluster in which more individuals (45%) indicate that their car usage has increased, instead of decreased (21%), after starting car sharing.

Cluster 6: Sceptical occasional car sharers

The sceptical occasional car sharers are found not to be particularly motivated to use shared cars. Besides the cost motive and the use of shared cars instead of insufficient public transport, members show no positive scores on the motives. Furthermore, members of this cluster have the lowest car sharing usage frequency.

Together with the fifth cluster, members of this cluster are the youngest car sharers and further distinguish themselves by being car sharing members for the shortest period of all clusters (49 months). Besides, they are slightly less highly educated and live less often in very highly urban areas than the other clusters. What further sets this cluster apart is that 62% of the members have either free on-street or private parking available to them. Therefore, it might not be surprising that car ownership is the highest of all clusters, with 32% owning at least one car. The higher car ownership might also explain the lower scores of these clusters on the utility and experienced effort related statements. Noticeable is that while car ownership is relatively high, 31% of the individuals in this cluster have disposed of a private car, which is the third highest of all clusters. This showcases that individuals do not need to be particularly motivated or use the shared car very often to dispose of a shared car. Together with the relatively high car ownership still present (31% owns a private car), the reduction in car ownership might indicate that members of this cluster have disposed of their second or third car since starting car sharing. Lastly, the high share of private cars as a substitution for the shared car, combined with the lowest share of public transport as a substitution, indicates that members in this cluster are less public transport oriented.

4. Discussion

The segmentation of station-based car sharers showed how six user groups differed in their motives for using car sharing and their related characteristics. Based on their motives, environmentally motivated frequent car sharers and highly conscious car sharers seem to make a deliberate choice to use car sharing services. Their relatively high level of car sharing use combined with the substantial reduction in car ownership indicate that these groups specifically use shared cars as a replacement for private car use. Therefore, station-based car sharing proves to be an effective way to reduce car ownership for these user groups. These user groups show that the high car ownership reductions found in other studies are indeed possible and can be explained through the distinct car sharer

profiles (Jochem et al., 2020; Nijland & van Meerkerk, 2017; Schreier et al., 2018).

Conversely, environmentally-sceptical utility-focused car sharers have a substantially lower impact on car ownership due to their already low initial car ownership. In fact, the results showed that car sharing led to an increase among the members of this cluster, which confirms that car sharing may also have a negative impact in terms of sustainability (María Arbeláez Vélez et al., 2021). However, as this cluster is rather small it could be argued that the improvement in terms of transportation equity, as formerly carless people are enabled to use a car when they need one, outweigh the negative impacts on the environment. The other, more substantial, utility-focused group shares similarities with the environmentally-sceptical utility-focuses car sharers. However, members of this group are less sceptical in regard to environmental motives, and more individuals in this group disposed of a car as their initial car ownership was higher. For both groups, the shared car is primarily a useful addition to their mobility options. This shows how car sharing impacts are very dependent on the individual, and it might explain why some studies find a small or even negative effect of car sharing on car ownership (Becker et al., 2018; Bucsky & Juhász, 2022; Kolleck et al., 2021).

Furthermore, the sceptical occasional car sharers demonstrated that cost benefits and perceived public transport insufficiency are enough to motivate those individuals to dispose of private cars, even with lower levels of car sharing use. Moreover, the relatively high level of car ownership still present in this group indicated that also second cars were disposed of, exemplifying an impact of car sharing, which was not found for the other user groups. These findings hold to a lesser degree also for the moderately motivated car sharers, in which similar patterns are found.

Besides these different impacts related to different user groups, this work provides some other new insights. First of all, this study finds that the 'influence of others' is not an important motive for most station-based car sharers, while multiple studies find this to be the most important predictor of the intention to use car sharing (Curtale et al., 2021; Mattia et al., 2019). This suggests that the opinions of others are important when considering new ways of transportation, such as shared cars, but once a service is used, it is no longer regarded as an important aspect. Furthermore, the fact that cluster with the highest car sharing use (the environmentally motivated frequent car sharers), also has the highest average household size (3.1). This shows that while smaller households are often associated with a greater intention to use shared cars, this does not always hold for the actual use (Amirnazmiafshar & Diana, 2022; Ceccato & Diana, 2021; Prieto et al., 2017).

In addition, this study clarified the relationship between station-based car sharing and public transport. More specifically, it shows that car sharers are primarily public transport oriented but use a shared car when public transport is perceived insufficient for the intended trip. This highlights the complementary nature of station-based car sharing to public transport. Furthermore, when the hypothetical modal substitution of the shared cars was weighed for the car sharing use of the respondents, it turned out that the shared car substituted mostly private car trips. This differs from the study of (Nijland & van Meerkerk, 2017), which found that car sharing primarily substitutes public transport and highlights the general positive influence of car sharing on sustainable travel behaviour.

Moreover, this study was among the first to include the influence of different parking facilities on car sharing use. While different parking facilities showed a significant influence on belonging to a distinct user group, it was not possible to determine whether strict parking facilities actually contributed to people's decision to start car sharing. Clarifying the relations between stricter parking policies, the decision to become a car sharer and car ownership would provide valuable knowledge on the role of car sharing in reducing car ownership. To do so, future studies could consider estimating the impact of introducing stricter parking facilities alongside the introduction of car sharing services in that same area.

5. Conclusion

By the identification of six distinct station-based user profiles, this study showed that one specific type of car sharer does not exist and that implications of stimulating car sharing use differ per user group. From this segmentation, it can be concluded that the amount car sharing use is not the main determinant for the positive impacts related to car sharing, rather

is the profile of the individual that uses the shared car. Therefore, car sharing companies and policymakers should recognise the identified differences between user groups when designing strategies to promote car sharing use or enhance sustainable transportation.

Considering the desire to reduce car ownership in urban areas, governmental institutions should focus on increasing the number of car sharers, rather than increasing the frequency of car sharing use. This is supported by substantial car ownership reduction for all users, even for more sceptical and occasional users. Additionally, it might be more effective to focus on areas with higher levels of car ownership, as addressing groups with already low car ownership might cause an increase in car use. However, as the need to reduce car ownership in very urbanised areas might be higher than the need to reduce car use, attracting more car sharers in highly urbanised areas would also be an effective strategy. Furthermore, as shared cars are found to be a useful but necessary supplement to public transport for car-less individuals, governments could explore ways to improve and stimulate the use of both modes next to each other, to satisfy the travel needs of car-less individuals. This particularly applies to public transport users who retain a car for occasional trips that could potentially be replaced by a shared car.

Car sharing companies could exploit the identified user groups by advertising the specific strengths and benefits of shared cars to the different (potential) user groups. For the utility-focused groups, the perceived benefits in terms of convenience, costs and having an extra transportation option should be promoted, while for the environmental and highly conscious car sharers, the sustainable image should be highlighted. To the moderately motivated and sceptical car sharers, the possibility of disposing of a second car and the added value of a shared car as an additional travel option could specifically be promoted.

This research has certain limitations and suggestions for future research. A limitation is the violation of the assumption of local independence, as not all associations between the indicators are explained by the identified clusters. This might have caused bias in the cluster outcome, and therefore future research could consider reducing the number of correlated indicators by using a factor analysis prior to the LCCA. Another limitation is the absence of a control group to compare the results. Including station-based car sharers of different companies or even other types of car sharing, such as zone-based or free-floating, would put the results into a broader perspective. Furthermore, the underrepresentation of young people in the sample might have influenced the results as young people may have different motives for using shared cars, especially concerning the environmental and cost-related aspects. Therefore a future study with a representative sample is recommended. This study could also include different car sharing users to reveal if similar user groups exist among other station-based, zone-based or free-floating car sharers.

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B

Overview of factors identified in the literature

Table B.1 presents an overview of the factors discussed in the previous section and the expected impact that they have on the intention to use car sharing. The impact of the factors is expressed with either a (-) for a negative relation between the factor and the intention to use car sharing, a (+) for a positive relation and a (0) if no significant effect was found. A negative relation means that if the factor increases, the intention to use car sharing decreases and vice versa. A positive relation means that if the factor increases, the intention to use car sharing increases as well.

Table B.1: Factors impacting the intention to use car sharing

Factor	**Expected impact on intention**	**Reference**
Socio-demographic		
Age	-	Aguilera-García et al. (2022), Becker et al. (2017), Burghard and Dütschke (2019), Ceccato and Diana (2021), Hjorteset and Böcker (2020), and Prieto et al. (2017)
Gender (male)	+	Aguilera-García et al. (2022), Becker et al. (2017), Burghard and Dütschke (2019), Ceccato and Diana (2021), and Prieto et al. (2017)
	0	Hjorteset and Böcker (2020) and Münzel et al. (2019)
Education level	+	Aguilera-García et al. (2022), Becker et al. (2017), Burghard and Dütschke (2019), Ceccato and Diana (2021), Münzel et al. (2019), and Prieto et al. (2017)
	-	Acheampong and Siiba (2020)
Income	+	Alonso-González et al. (2021) and Clewlow (2016)
	0	Hjorteset and Böcker (2020) and Münzel et al. (2019)
Household size	-	Ceccato and Diana (2021) and Prieto et al. (2017)
	0	Aguilera-García et al. (2022)
Occupation (full-time employed)	+	Becker et al. (2017) and Hjorteset and Böcker (2020)

Car ownership within household	-	Becker et al. (2017), Burghard and Dütschke (2019), Ceccato and Diana (2021), and Hjorteset and Böcker (2020)
Car sharing service related		
Car sharing costs	-	Papu Carrone et al. (2020) and Wang et al. (2021)
Proximity of shared car	+	Paundra et al. (2017), Schreier et al. (2018), and Wang et al. (2021)
Spatial Characteristics		
Residential density	+	Aguilera-García et al. (2022), Prieto et al. (2017), and Wang et al. (2021)
Private parking available	-	Ceccato and Diana (2021)
Psychological constructs		
Environmental concerns	+	Guglielmetti Mugion et al. (2019), Hjorteset and Böcker (2020), and Münzel et al. (2019)
	0	Becker et al. (2017) and Ramos et al. (2020)
	-	Aguilera-García et al. (2022) and J. Kim et al. (2017)
Social motive	+	Curtale et al. (2021), H. Kim and Jan (2021), and Peterson and Simkins (2019)
	0	Hjorteset and Böcker (2020)
Utilitarian motive	+	Acheampong and Siiba (2020), Curtale et al. (2021), and H. Kim and Jan (2021)

Table B.2: Factors found in literature impacting the usage of car sharing

Factor	**Impact on usage**	**Reference**
Socio-demographic variables		
Age	+	D. Kim et al. (2015)
	-	Aguilera-García et al. (2022), Becker et al. (2017), and Burkhardt and Millard-Ball (2006)
Gender (male)	+	Becker et al. (2017)
	-	D. Kim et al. (2015)
Education level	+	Millard-Ball et al. (2005) and Münzel et al. (2019)
Income	+	Aguilera-García et al. (2022) and Millard-Ball et al. (2005)
	-	Aguilera-García et al. (2022) and D. Kim et al. (2015)
Occupation (employed)	+	Becker et al. (2017)
Occupation (student)	-	Aguilera-García et al. (2022)
Car ownership within household	-	Aguilera-García et al. (2022) and Becker et al. (2017)
Public transit subscription	+	Münzel et al. (2019)

	-	Becker et al. (2017)
Psychological constructs		
Environmental concerns	+	D. Kim et al. (2015), Mattia et al. (2019), Millard-Ball et al. (2005), and Schaefers (2013)
	0	Becker et al. (2017) and Münzel et al. (2019)
	-	Aguilera-García et al. (2022)
Social motive	+	D. Kim et al. (2015)
Perceived behavioral control	+	Mattia et al. (2019)
Utilitarian motive	+	D. Kim et al. (2015)
Convenience motive	+	D. Kim et al. (2015)
Variety Seeking Lifestyle	+	Aguilera-García et al. (2022)

Table B.3: Impacts associated with car sharing usage

Factor	**Impact of CS on factor**	**Reference**
Car ownership	-	Becker et al. (2018), Jochem et al. (2020), Kolleck et al. (2021), Millard-Ball et al. (2005), Nijland and van Meerkerk (2017), Oldenburger et al. (2019), and Schreier et al. (2018)
	0	Bucsky and Juhász (2022) and Kolleck et al. (2021)
Vehicle kilometres travelled	-	María Arbeláez Vélez et al. (2021), Nijland and van Meerkerk (2017), and Oldenburger et al. (2019)
	+	María Arbeláez Vélez et al. (2021)
GHG emissions	-	Nijland and van Meerkerk (2017)
	+	María Arbeláez Vélez et al. (2021)
Modal shift (% car)	+	Becker et al. (2017) and Papu Carrone et al. (2020)
	-	Becker et al. (2017, 2018)
Accessibility of formerly carless households	+	Shaheen et al. (2020)

C
Survey Questions

Onderstaande vragen gaan over het bezit van een auto in jouw situatie.

1. Over hoeveel auto's beschikt jouw huishouden op dit moment?*

Kies één antwoord

- 0
- 1
- 2 of meer

2. Heb je (één van) je auto('s) weggedaan, sinds je Greenwheels gebruikt?*

Kies één antwoord

- 0
- 1
- 2 of meer

Sectie 2 - Autolocaties

6. Wat is de (parkeer)situatie in de omgeving van jouw huis?*

Kies één antwoord

- Ik heb een eigen parkeerplaats (eigen terrein, garage).
- Hier geldt gratis parkeren.
- Hier geldt vergunning/betaald parkeren op straat.
- Anders, namelijk...

18. Wat zijn je meestvoorkomende redenen om gebruik te maken van een Greenwheels-deelauto?*

Selecteer max. 3 antwoorden.

- Boodschappen/winkelen
- Visite bij vrienden/familie
- Sport, hobby of uitgaan
- Vakantie of weekendje weg
- Van en naar werk of studie
- Spullen ophalen of brengen
- Anders, namelijk....

21. Stel dat de Greenwheels-deelauto niet bestond; met welk vervoermiddel zou je dan de ritten hebben gemaakt?*

We bedoelen de ritten die je nu met Greenwheels maakt. Kies het meest waarschijnlijke antwoord.

Selecteren...

22. Verwacht je in de toekomst minder vaak of vaker gebruik te maken van Greenwheels?*

Kies één antwoord

Selecteren...

Sectie 5 - Gebruiksmotieven

De volgende vragen gaan over jouw motieven om gebruik te maken van Greenwheels deelauto's. Kies bij elke vraag het antwoord dat het best bij jou past.

23. Ik maak gebruik van deelauto's, omdat deze een lagere uitstoot hebben in vergelijking met een eigen auto.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

-2 -1 0 1 2

Volledig mee oneens Volledig mee eens

24. Ik maak gebruik van deelauto's, omdat ik zo bijdraag aan het verminderen van de verkeersdrukte in mijn woonplaats.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

25. Ik maak gebruik van deelauto's, omdat ik zo ruimte vrijmaak voor voor andere/leukere dingen in mijn woonplaats.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

26. Ik maak gebruik van deelauto's, omdat het goedkoper is dan het bezitten van een eigen auto.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

27. Ik maak gebruik van deelauto's, omdat het gemakkelijker is dan het bezitten van een eigen auto.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

28. Ik maak gebruik van deelauto's, omdat het de kwaliteit van mijn reis verbetert ten opzichte van de vervoerswijze die ik anders had gebruikt.

Kies het meest passende antwoord. Volledig onwaar: -2 | Deels onwaar: -1 | Neutraal/Weet ik niet: 0 | Deels waar: +1 | Volledig waar: +2

29. Ik maak gebruik van deelauto's, omdat ik dan niet hoef te zoeken naar een parkeerplek voor mijn auto.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

30. Mijn omgeving stimuleert mij om gebruik te maken van deelauto's.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

31. Ik maak gebruik van deelauto's, omdat ik het leuk vind om auto te rijden.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

32. Ik maak gebruik van deelauto's, omdat het delen van goederen met anderen mij aanspreekt.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

33. Ik vind een deelauto gebruiken gemakkelijk.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

34. Ik ben tevreden over de afstand van mijn huis tot de deelauto.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

35. Deelauto's zijn niet altijd beschikbaar als ik er gebruik van wil maken.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

Sectie 6 - Greenwheels en het OV

36. Hoe vaak maak je gebruik van het openbaar vervoer?*

Denk aan de trein, bus, tram en/of metro.

Selecteren...

37. Sinds ik Greenwheels ben gaan rijden, ben ik _____ het openbaar vervoer gaan gebruiken.*

Kies één antwoord

- Veel minder vaak
- Minder vaak
- Even vaak
- Vaker
- Veel vaker

38. Ik maak gebruik van Greenwheels om van een treinstation naar mijn eindbestemming te reizen.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

39. Ik gebruik Greenwheels voor het reizen naar plekken waar ik niet makkelijk kom met het openbaar vervoer.

Kies het meest passende antwoord. Helemaal mee oneens: -2 | Deels mee oneens: -1 | Neutraal: 0 | Deels mee eens: +1 | Helemaal mee eens: +2

Sectie 7 - Demografie

40. Uit hoeveel volwassenen bestaat je huishouden?

Vul getal in...

41. Uit hoeveel kinderen t/m 17 jaar bestaat je huishouden?

Geen kinderen in je huishouden? Vul dan 0 in.

Vul getal in...

42. Wat is de hoogste opleiding die je hebt afgemaakt?

Kies één antwoord

- Geen/basisonderwijs
- Middelbaar onderwijs (vmbo/havo/vwo) of mbo1
- Mbo2-4
- Hbo/wo-opleiding
- Zeg ik liever niet
- Anders, namelijk

43. Tot slot, heb je nog een opmerking, toevoeging of suggestie voor Greenwheels?

Typ één of enkele woorden...

999

D

Clarification of the results

D.1. Car sharing motives related to different membership lengths

Table D.1 shows the average motives scores for Greenwheels members with varying membership lengths. Questions were asked on a 5-point Likert scale.

Table D.1: Average motives scores for groups with varying membership lengths

Membership duration	**1-2 years**	**2-10 years**	**10+ years**
% of total sample	*(27%)*	*(43%)*	*(30%)*
Environmental motives			
Reduce emissions	3.13	3.10	3.24
Reduce traffic	3.43	3.52	3.84
Create public space	3.02	3.18	3.37
Utility motives			
Cheaper than a private car	4.34	4.51	4.50
Easier than a private car	3.92	4.05	4.31
Improves trip quality	3.57	3.60	3.79
No parking search	2.95	2.95	3.36
Social motives			
Influence of others	3.03	2.93	2.87
Joy of driving	3.12	2.73	2.54
Sharing of goods	3.49	3.50	3.75
Experienced effort to use			
Use is easy	4.28	4.28	4.37
Proximity to shared car	4.37	4.48	4.69
Shared car not available	2.95	2.77	2.51
Public transport motives			
As last-mile solution for a train trip	1.86	2.04	2.32
Instead of insufficient PT	4.30	4.40	4.61

D.2. Distributions of indicators

The figures in this section show how the questions that measure the indicators were answered. Therefore they provide the distribution of indicators, which all range from 1 to 5 as all questions were asked on a 5-point Likert scale.

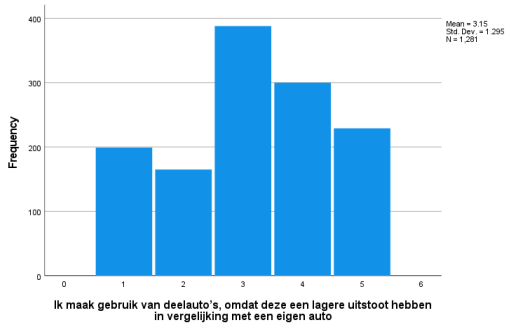

Figure D.1: For me, a motive to use shared cars is the lower emission related to shared cars compared to private cars

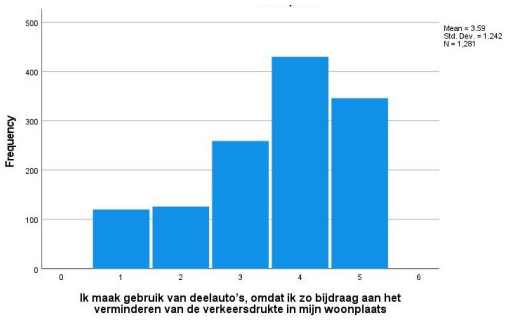

Figure D.2: A reason for me to use shared cars is that by doing so I contribute to reduction traffic in my city

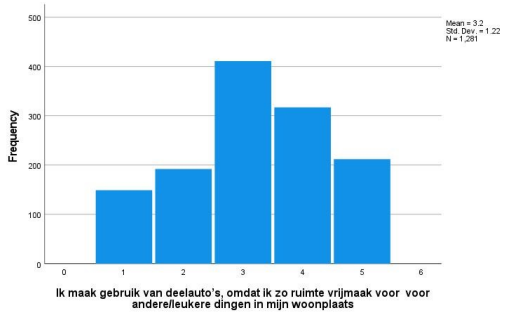

Figure D.3: I use shared cars because it contributes to creating extra space for other/enjoyable things in my city

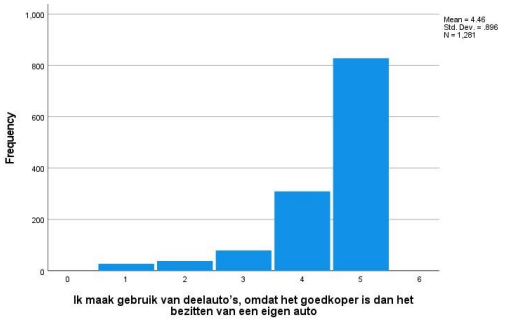

Figure D.4: I use shared cars because it enables me to save money compared to owning a private car

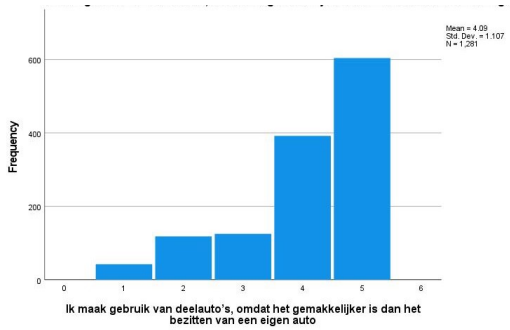

Figure D.5: 'I use shared cars because it is easier than owning a private car

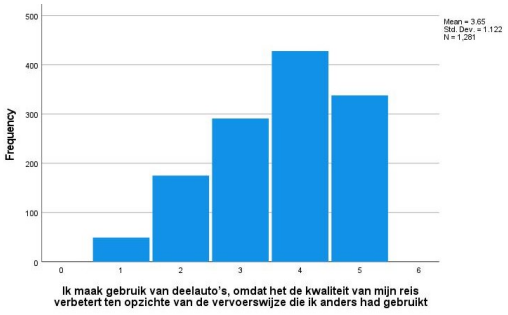

Figure D.6: I use shared cars because it improves the quality of my trip compared to the mode of transport I would have used otherwise

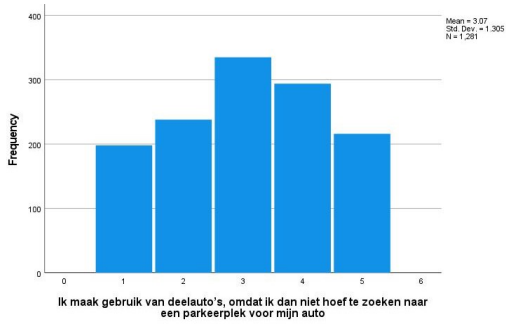

Figure D.7: I use shared cars because it means I do not have to look for a parking place for my car

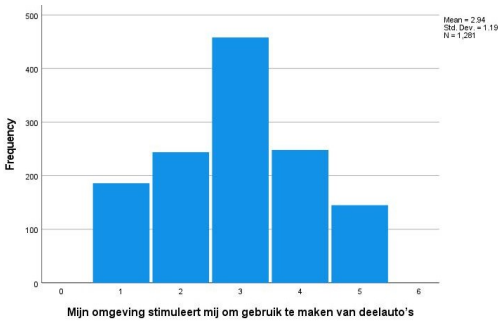

Figure D.8: People around me encourage me to use shared cars

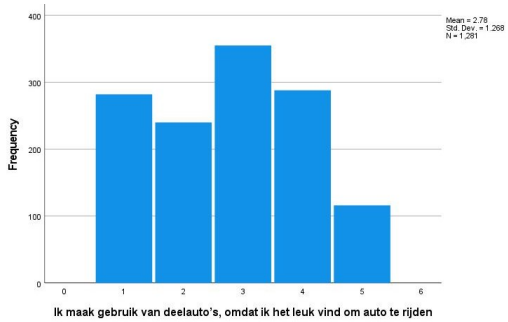

Figure D.9: I use shared cars because I enjoy driving in a car

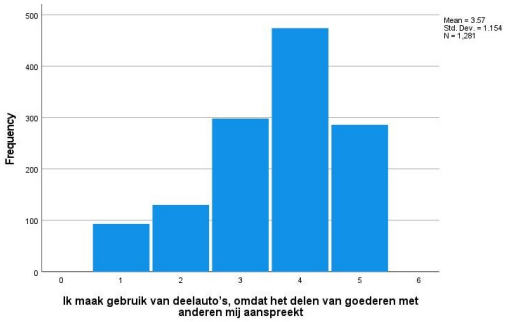

Figure D.10: I use car sharing services because sharing goods with others appeals to me

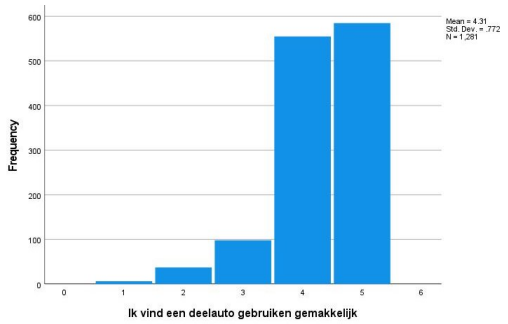

Figure D.11: I find it easy to use car sharing services

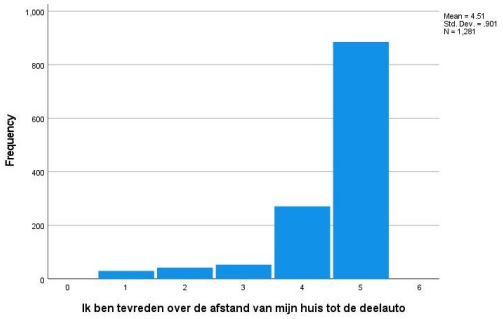

Figure D.12: I am satisfied with the distance from my house to the shared cars I use

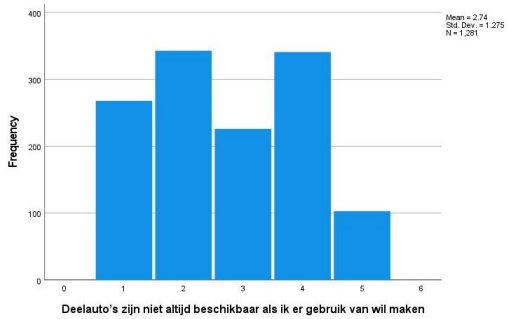

Figure D.13: Shared cars are not always available when I intend to use them

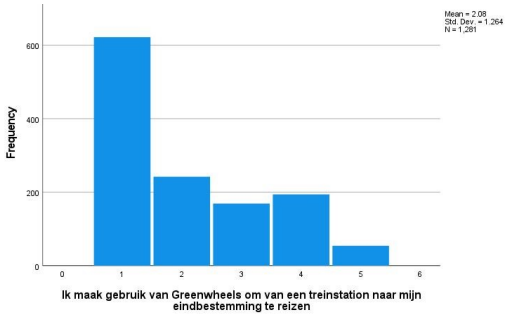

Figure D.14: I use shared cars to travel from a train station to my final destination

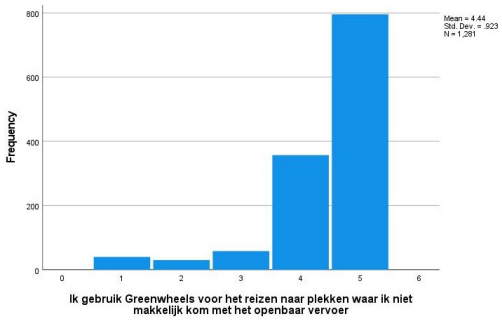

Figure D.15: I use car sharing for trips where public transport is insufficient

D.3. Parameters of the estimated Latent Class Cluster model with covariates

Table D.2: Parameters of the estimated latent class cluster model with covariates

Prediction of the indicators	CL.1	Cl.2	Cl.3	Cl.4	Cl.5	Cl.6	Wald	p-value
Usage frequency	-0.027	0.037	0.134	0.033	-0.008	-0.169	8.440	0.13
Reduce emissions	0.094	0.276	0.991	1.201	-1.322	-1.238	185.671	0.000
Reduce traffic	-0.375	0.362	2.154	4.769	-3.475	-3.436	173.357	0.000
Create public space	0.207	0.534	1.518	2.994	-2.638	-2.614	224.565	0.000
Cheaper than a private car	-0.748	0.963	-0.682	0.747	0.764	-1.044	78.840	0.000
Easier than a private car	-0.909	0.758	-0.780	2.096	0.400	-1.546	115.657	0.000
Improves trip quality	-0.248	0.179	-0.181	0.431	0.467	-0.649	75.595	0.000
No parking search	-0.107	0.350	-0.018	0.922	-0.102	-1.045	119.529	0.000
Influence of others	-0.079	0.249	-0.056	0.664	-0.058	-0.721	87.364	0.000
Joy of driving	0.001	0.057	-0.071	0.172	-0.033	-0.134	8.139	0.15
Sharing of goods	-0.293	0.096	0.669	1.104	-0.631	-0.945	164.150	0.000
Use is easy	-1.234	0.950	-0.309	14.97	0.607	-1.512	178.403	0.000
Proximity to shared car	-1.445	2.250	-0.764	0.871	0.687	-1.599	75.338	0.000
Shared car not available	0.367	-0.391	0.108	-0.142	-0.316	0.374	100.975	0.000
As last-mile solution for a train trip	0.065	0.049	0.247	0.278	-0.233	-0.407	38.602	0.000
Instead of insufficient PT	-0.249	0.050	0.165	0.575	-0.062	-0.4800	42.437	0.000
Intercepts	1	2	3	4	5	Wald	p-value	
Usage frequency	0.394	0.217	0.221	-0.144	-0.689	907.596	0.000	
Reduce emissions	-0.124	-0.121	1.332	1.708	-0.046	205.707	0.000	
Reduce traffic	-2.874	-0.121	1.332	1.708	-0.046	185.375	0.000	
Create public space	-0.810	0.777	1.337	0.326	-1.629	272.956	0.000	
Cheaper than a private car	-2.796	-1.664	-0.1913	1.759	2.893	272.956	0.000	
Easier than a private car	-3.097	-1.001	-0.004	1.832	2.270	156.340	0.000	
Improves trip quality	-1.695	-0.207	0.438	0.872	0.591	210.312	0.000	
No parking search	-0.255	0.088	0.431	0.165	-0.430	88.611	0.000	
Influence of others	-0.224	0.126	0.746	0.037	-0.686	244.624	0.000	
Joy of driving	0.180	0.015	0.396	0.171	-0.762	113.664	0.000	
Sharing of goods	-1.221	-0.4910	0.553	0.992	0.168	241.015	0.000	
Use is easy	-4.797	-1.708	0.433	3.006	3.065	392.654	0.000	
Proximity to shared car	-3.862	-2.090	-0.473	2.392	4.032	121.763	0.000	
Shared car not available	0.157	0.482	0.047	0.349	-1.034	163.725	0.000	
As last-mile solution for a train trip	1.336	0.338	-0.106	-0.079	-1.489	406.129	0.000	
Instead of insufficient PT	-1.317	-1.417	-0.620	1.274	2.081	515.904	0.000	
Prediction of latent class membership	Cl.1	Cl.2	Cl.3	Cl.4	Cl.5	Cl.6	Wald	p-value
Intercept	1.798	1.161	-0.261	-3.175	0.949	-0.471	12.986	0.024
Covariates								
Age	-0.003	0.001	0.006	0.027	-0.024	-0.008	22.759	0.000
Membership length in months	-0.003	0.003	0.003	0.002	0.004	-0.008	32.377	0.000
Household size	0.041	-0.228	0.237	0.029	-0.012	-0.066	20.309	0.001
Free on-street parking	-0.295	-0.714	-0.316	1.220	-0.956	1.061	61.317	0.000
Private parking spot	-0.394	-0.939	-0.072	0.259	-0.679	1.825		
Paid/permit on-street parking	-0.788	-0.255	-0.636	1.681	-0.422	0.420		
Other	1.477	1.908	1.024	-3.159	2.056	-3.306		

D.4. Chi-squared tests car ownership

The following tables show the chi-squared tests for the associations between parking facilities and car ownership and car ownership and car sharing use.

First of all, there is a significant association between the car ownership and parking facilities, as the X^2(6,N=1281) = 58.9, for a critical value of 12.59 at 5% significance level.

Table D.3: Contingency table for car ownership and parking facilities

			Paid/permint on-street	Free on-street	Private spot	Other	Total
Car ownership in household	0	Count	690	272	130	13	1105
		Expected count	659.9	275.2	158.7	11.2	1105
		% over column	90.2%	85.3%	70.7%	100%	86.3%
	1	Count	71	46	47	0	164
		Expected count	97.9	40.8	23.6	1.7	164
		% over column	9.3%	14.4%	25.5%	0.0%	12.%
	2+	Count	4	1	7	0	12
		Expected count	7.2	3.0	1.7	0.1	12
		% over column	0.5%	0.3%	3.8%	0.0%	0.9%
Total		Count	765	319	184	13	1281
		Expected count	765	319	184	13	1281
		% over column	100%	100%	100%	100%	100%

There is a significant association between the car ownership and car sharing usage frequency, as the X^2(8,N=1281) = 27.44, for a critical value of 15.51 at 5% significance level.

Table D.4: Contingency table for car ownership and car sharing usage frequency

			1-5 times per year	6-11 times per year	1-2 times per month	2-4 times per month	Weekly or more	Total
Car ownership in household	0	Count	227	247	268	195	118	1105
		Expected count	299.3	253.6	258.8	183.7	109.6	1105
		% over column	79.8%	84.0%	89.3%	91.5%	92.9%	86.3%
	1	Count	64	43	30	18	9	164
		Expected count	44.4	37.6	38.4	27.3	16.3	164
		% over column	18.4%	14.6%	10.0%	8.5%	7.1%	12.%
	2+	Count	6	4	2	0	0	12
		Expected count	3.3	2.8	2.8	2.0	1.2	12
		% over column	1.7%	1.4%	0.7%	0.0%	0.0%	0.9%
Total		Count	347	294	300	213	127	1281
		Expected count	347	394	300	213	127	1281
		% over column	100%	100%	100%	100%	100%	100%

D.5. Preference for station-based car sharing in survey

Figure D.16 shows how the 1281 respondents think about zone-based car sharing compared to station-based car sharing.

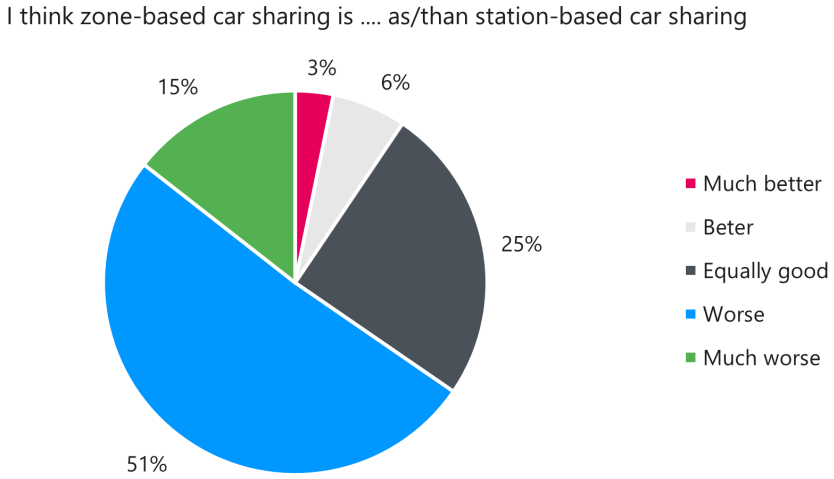

Figure D.16: Preference for station-based compared to zone-based