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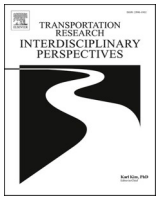

Comparing carsharing users' characteristics, travel behavior, and car ownership under increasing carsharing market penetration: A repeated cross-sectional analysis

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ABSTRACT

This study examines the extent to which the maturation of a carsharing market is associated with changes in the characteristics of its users and its mobility impacts. The analysis draws on two repeated cross-sectional surveys of the general population in Hamburg, Germany, a city that has experienced a substantial increase in carsharing market penetration in recent years, largely driven by the expansion of free-floating carsharing services. During the first survey period (2016/2017), carsharing in Hamburg was still in an early adopter phase, whereas by the second period (2023/2024) it had become a mainstream mobility option. Between these periods, the share of carsharing users among licensed drivers increased from 13 % to 24 %. Despite this transition, the sociodemographic profile of carsharing users remained remarkably stable. In both periods, users were predominantly male, young or middle-aged, highly educated, comparatively affluent, and residents of the city center. Accordingly, only limited convergence between users and non-users was observed. Likewise, travel behavior and car ownership among carsharing users changed little. Although carsharing users consistently owned fewer cars than non-users, the prevalence of car-free households did not increase as the market matured. At the same time, carsharing users with and without private car ownership became more similar in their sociodemographic characteristics, suggesting that the association between carsharing and car ownership became less sociodemographically selective over time. Overall, the findings indicate that market growth alone is insufficient to broaden the appeal and impacts of carsharing, highlighting the need for targeted transport policy interventions to engage underrepresented population groups.

1. Introduction

Business-to-consumer (B2C) carsharing has experienced substantial growth worldwide in recent years, as reflected in the increasing number of users and providers, as well as expanding fleet sizes (Shaheen & Cohen, 2020; Wang et al., 2024). While carsharing was widely regarded as a niche market until only a few years ago, it has increasingly become an attractive mobility option for substantial segments of the population, at least in highly urbanized areas. In Germany, Europe's largest B2C carsharing market (Münzel et al., 2020), 23 % of all households in cities with more than 500,000 inhabitants held at least one carsharing membership in 2023/2024. In cities with more than one million inhabitants, this share had already reached approximately one-third (Belz et al., 2025).

From a transport policy perspective, carsharing is frequently considered a promising approach for reducing car dependence and promoting more sustainable mobility patterns. Numerous studies from different regions of the world have shown that carsharing services can contribute to reducing private car ownership (e.g., Clewlow, 2016; Giesel & Nobis, 2016; Jain et al., 2022; Ko et al., 2019; Le Vine & Polak, 2019; Mishra et al., 2015; Ye et al., 2021). These reductions in private car ownership are often accompanied by broader shifts in travel behavior toward more sustainable modes of transportation (Becker et al., 2017; Chapman et al., 2020; Kent, 2014; Xu et al., 2026). At the same time, the mobility impacts of carsharing are not distributed evenly across all user groups. Among individuals who already lived without a private car before joining a carsharing service, carsharing may have little potential to reduce car use and, in some cases, may even increase it (Nijland & van Meerkerk, 2017; Vejchodská et al., 2024). Similar patterns have been reported for users who treat carsharing as a complement

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rather than a substitute for private car ownership (Chapman et al., 2020; Garrett et al., 2021; Jain et al., 2020), as well as for users who increase their household car ownership after adopting carsharing (Jain et al., 2020). Nevertheless, the available evidence indicates that these potentially adverse effects are, in many cases, more than offset by the—often comparatively larger—reductions in car use among users who reduce or give up private car ownership after adopting carsharing (Lane, 2005; Martin & Shaheen, 2011b; Martin et al., 2021). As a result, several studies conclude that carsharing has the potential to reduce overall greenhouse gas emissions (Kurisu et al., 2023; Martin & Shaheen, 2011a; Nijland & van Meerkerk, 2017), even when rebound effects, such as the comparatively shorter service life of carsharing vehicles relative to privately owned cars, are taken into account (Amatuni et al., 2020; Nong et al., 2025).

As carsharing services and memberships have expanded, academic interest in carsharing has increased accordingly. In particular, the influence of sociodemographic characteristics on the willingness to use carsharing has been studied extensively (e.g., Amirnazmiafshar & Diana, 2022; Carmen et al., 2021; Hjorteset, 2024; Kopp et al., 2015; Münzel et al., 2019; Prieto et al., 2017; Ramos et al., 2023). Some studies have further investigated whether, beyond carsharing use itself, its effects on users' private car ownership are also socio-demographically selective, that is, whether certain user groups are more likely than others to forgo private car ownership (e.g., Giesel & Nobis, 2016; Ko et al., 2019; Le Vine & Polak, 2019; Namazu & Dowlatabadi, 2018; Ye et al., 2021).

However, much of the existing literature is based on studies of carsharing services that were still in the early stages of diffusion and had therefore attracted only relatively small segments of the population as users. In contrast, relatively few studies have focused on the users and impacts of more established carsharing services (Hjorteset, 2024; Van der Linden et al., 2025; Xu et al., 2024; Zhang et al., 2024), which is likely due to the still limited number of suitable study areas and case studies. Although the origins of professionally organized carsharing can be traced back to Switzerland and Germany in the 1980s (Truffer, 2003), modern carsharing still represents a niche innovation in many places. This is largely attributable to the substantial transformation of carsharing since the 2010s following the diffusion of modern information and communication technologies. Only with the widespread availability of mobile internet did carsharing become attractive to broader segments of the urban population. This development is particularly evident in the case of free-floating carsharing, which does not rely on fixed stations and was first introduced to the general public in the German city of Ulm in 2009 (Firnkorn & Müller, 2011). Since then, it has become the dominant carsharing model in Germany in terms of user numbers (Belz et al., 2025).

Applying the Diffusion of Innovations theory (Rogers, 2003) to carsharing suggests that much of the existing research on carsharing use is likely to be based primarily on early adopters. The Diffusion of Innovations theory is a widely applied theoretical framework that describes how innovations spread across different adopter groups, which differ, among other respects, in their attitudes and sociodemographic characteristics. Early adopters are typically younger, more highly educated, have higher incomes, are more receptive to new technologies, and are more willing to take risks. Accordingly, these characteristics have been documented in several studies of early carsharing adopters (Burghard & Dütschke, 2019; Dyba & Kisiała, 2024; Kawgan-Kagan, 2015; Kopp et al., 2015; Namazu et al., 2018; Le Vine & Polak, 2019; Wittwer & Hubrich, 2018).

At the same time, the literature provides only limited insights into the users and mobility impacts of more mature and established carsharing systems that have clearly moved beyond the early adopter phase. Such insights are important from several disciplinary and stakeholder perspectives. From an economic and supply-side perspective, broader market penetration allows for more robust assessments of the medium- and long-term development of carsharing demand and the user segments that contribute to the economic viability of carsharing systems. From an environmental perspective, the key question is how the mobility impacts associated with carsharing evolve over time and whether more mature carsharing services differ from less established ones in their potential to substitute for private car ownership. From the perspective of transport equity, it is important to understand which population groups are reached as carsharing becomes more widely established and whether access to the associated mobility opportunities is distributed equitably across social groups and space or whether existing inequalities are maintained or even reinforced.

Against this background, the present study examines potential changes in the user base and mobility-related impacts of carsharing in Hamburg, Germany's second-largest city. The empirical analysis draws on two comprehensive and representative population-based surveys conducted in 2016/2017 and 2023/2024. Rather than focusing on individual carsharing services, the study investigates city-wide changes in the carsharing user base as carsharing memberships became more widespread. From the first to the second survey period, carsharing reached a comparatively high level of market penetration in Hamburg. Assuming, for the sake of simplicity, that all adult holders of a driver's license constitute the potential user base, the share of adopters amounted to 13 % in the first survey period and increased to 24 % in the second. According to the Diffusion of Innovations theory, an innovation typically moves beyond the early adopter phase once it reaches an adoption level of approximately 16 % (Moore, 2014; Rogers, 2003). Consequently, the carsharing user base in Hamburg is likely to have shifted from early adopters toward more mainstream users between the two survey periods. This development allows the present study to examine how the sociodemographic profile, travel behavior, and private car ownership of carsharing users changed as carsharing became more widely diffused. Specifically, the following four research questions guide the analysis:

(1) How did the sociodemographic profile of carsharing users change over time?
(2) Have carsharing users become more similar to non-users in their sociodemographic characteristics over time?
(3) How did the travel behavior of carsharing users change over time?
(4) How did the prevalence and sociodemographic patterns of private car ownership among carsharing users change over time?

Taken together, these research questions explore how the transformation of carsharing from a niche innovation to a mainstream mobility option is reflected in the composition of its user base and in users' mobility practices. They also provide a basis for assessing whether more mature carsharing services continue to represent a sociodemographically selective mode of transportation or whether their user base and mobility impacts have become more broadly distributed across population groups over time.

The remainder of the article is structured as follows. **Section 2** reviews the relevant literature on the adoption and mobility-related impacts of carsharing, with particular emphasis on differences between early and later adopters. **Section 3** describes the study area, data sets, and the methods used for data preparation and analysis. **Section 4** presents the empirical results, and **Section 5** discusses these results in the context of the existing literature and derives implications for transport policy.

2. Previous research

2.1. Evolution of carsharing user characteristics

The question of which sociodemographic characteristics distinguish actual or potential carsharing users has been the subject of numerous studies. There is broad consensus in the literature that carsharing users are predominantly male, young to middle-aged (i.e., typically younger

than 50), employed, and characterized by comparatively high levels of education and income (Amirnazmiafshar & Diana, 2022; Nansubuga & Kowalkowski, 2021). However, previous research provides a less consistent picture regarding the size and composition of the households in which carsharing users live. Much of the literature identifies carsharing users primarily as members of two-adult households without children (Giesel & Nobis, 2016; Wittwer & Hubrich, 2018). At the same time, single-person households (Chicco et al., 2022; Prieto et al., 2017) and larger households with children (Leroy et al., 2023; Xu et al., 2024) have also been identified as typical user groups in some contexts.

Because carsharing providers generally concentrate their services in cities, it is unsurprising that urban residents are overrepresented among carsharing users (Amirnazmiafshar & Diana, 2022; Carmen et al., 2021; Meelen et al., 2019; Münzel et al., 2019). Nevertheless, previous research indicates that, even within cities, carsharing users tend to live in particularly urban neighborhoods that are typically pedestrian-friendly and well served by public transportation (Giesel & Nobis, 2016; Kopp et al., 2015; Roblot et al., 2021; Wali et al., 2025; Witte et al., 2024).

Previous findings on the characteristics of carsharing users should, however, be interpreted in light of two important considerations. First, existing research suggests that the two major variants of B2C carsharing, free-floating carsharing (FFCS) and station-based carsharing (SBCS), differ to some extent in the sociodemographic profiles of their users. Comparative studies have shown, for example, that FFCS is more attractive to younger individuals, men, and people with higher incomes, whereas SBCS tends to attract a more socio-demographically diverse user base (Becker et al., 2017; Chicco et al., 2022; Giesel & Nobis, 2016; Namazu et al., 2018). Second, it must be acknowledged that much of the research on the characteristics of carsharing users has been conducted on services that were still in the early stages of diffusion. Consequently, the users examined in these studies largely correspond to the typical profile of early adopters described by the Diffusion of Innovations theory (Rogers, 2003).

To date, relatively little is known about whether and to what extent later generations of users differ from the early adopters of carsharing. Some studies focusing explicitly on early adopters discussed the possibility that the user base would gradually expand toward the broader population as carsharing services became more established (Burghard & Dütschke, 2019; Duncan, 2011; Le Vine & Polak, 2019). However, given the low adoption levels of carsharing until only a few years ago, such considerations remained largely hypothetical for a long time.

As carsharing has become more widely established, the first empirical studies have begun to compare users at different stages of the diffusion process. Aguilera-García et al. (2022), for example, compared users of long-established FFCS services in Munich with those of more recently introduced FFCS services in Madrid and found that users in the latter city were significantly younger and more tech-savvy. Namazu et al. (2018) compared early adopters of carsharing in Vancouver with non-users who were open to joining a carsharing service (i.e., potential future users) and demonstrated that later generations of users are likely to be less socio-demographically distinctive. This finding is consistent with a longitudinal study by Haustein (2021), in which residents of an FFCS service area in Copenhagen were surveyed in two waves approximately two years apart. By the second survey wave, the shares of women and older individuals among carsharing users had converged toward those observed in the general population.

Witte et al. (2024) employed latent class analysis to segment SBCS users in the Netherlands and showed that carsharing has expanded beyond the niche of young, highly educated professionals and is increasingly attracting families and individuals aged 50 years and older. Similar patterns were identified in a cluster analysis of carsharing users in Norway (Hjorteset, 2024). Here, too, classic early adopters continued to represent a substantial share of users, but carsharing was increasingly adopted by older individuals and households with children. Remarkably, Xu et al. (2024) found no significant effects of gender, age, or occupation on the likelihood of carsharing use in a study of residents of Utrecht's city center. The authors interpreted this finding as a consequence of the relatively advanced diffusion of carsharing in the city.

2.2. Evolution of carsharing impacts

In addition to the characteristics of carsharing users, a plethora of studies have examined the mobility-related impacts of carsharing, particularly its effects on private car ownership. There is extensive evidence that carsharing use is generally associated with lower levels of private car ownership (e.g., Clewlow, 2016; Giesel & Nobis, 2016; Jain et al., 2022; Ko et al., 2019; Le Vine & Polak, 2019; Mishra et al., 2015; Ye et al., 2021). Much more difficult to determine, however, is the extent to which lower levels of private car ownership are a consequence rather than a cause of carsharing adoption.

Longitudinal and quasi-longitudinal studies conducted in Germany (Shahram & Diana, 2025), as well as in the cities of Basel (Becker et al., 2018) and San Francisco (Cervero & Tsai, 2004), consistently found that private car ownership declined following the adoption of carsharing. In a survey of carsharing users in Melbourne, Jain et al. (2022) likewise observed a reduction in private car ownership after individuals joined a carsharing service; however, substantially more vehicles had already been disposed of during the year preceding carsharing adoption. Consistent with this finding, Mishra et al. (2019), using survey data from carsharing users and non-users in the San Francisco Bay Area, estimated that only about 17 % of the difference in private car ownership between the two groups could be attributed to a causal effect of carsharing. Most of the observed difference instead reflected differences in the propensity of certain population groups to adopt carsharing in the first place. In Copenhagen, Haustein (2021) even found no substantial effect of a free-floating carsharing service on private car ownership after controlling for users' pre-existing intention to give up their private cars.

Estimating the effect of carsharing on private car ownership is further complicated by the fact that reductions in car ownership after joining a carsharing service cannot necessarily be attributed to carsharing itself. Previous research has shown that declines in private car ownership among carsharing users are often triggered by broader life-course events—such as changes in household composition, residential relocation, or retirement—even though carsharing may facilitate or support the decision to relinquish a private car (Haustein 2021, Jain et al. 2020).

Although numerous studies have examined the relationship between carsharing use and private car ownership, comparatively little is known about whether this relationship changes as market penetration increases and later adopter groups enter the user base. While individuals without a private car are generally more likely to join carsharing than car owners (Carmen et al., 2021; Namazu et al., 2018; Xu et al., 2024; Wang & Song, 2024), some researchers have argued that, as carsharing becomes more established, it may increasingly attract private car owners as well (Duncan, 2011; Martin & Shaheen, 2011b). An important mechanism in this context is the so-called follower effect from the Diffusion of Innovations theory (Rogers, 2003), which describes how early adopters act as opinion leaders within their social networks and positively influence the attitudes of initially more hesitant individuals, thereby accelerating the diffusion of an innovation. While this follower effect was primarily discussed as a future scenario in earlier studies on carsharing (Burghard & Dütschke, 2019; Le Vine & Polak, 2019; Namazu et al., 2018), more recent research has also documented it empirically (Zhang et al., 2024).

Nevertheless, studies examining how the relationship between carsharing use and private car ownership differs between earlier and later adopters remain scarce and have produced mixed findings. Wittwer & Hubrich (2018), for example, compared cross-sectional data from users of a free-floating carsharing service in Hamburg collected in 2011 and 2016 and found a significant increase in the share of carsharing members who owned a private car. By contrast, Van der Linden et al.

(2025) found, based on a survey of users of a station-based carsharing service in the Netherlands, that individuals who had been registered with the service for a longer period were less willing to give up private car ownership.

Kim et al. (2019) conducted two cross-sectional surveys of users of several station-based carsharing services in Seoul at a four-year interval. They found not only an overall decline in private car ownership among carsharing users between the two survey waves but also that this effect extended to more socio-demographically diverse segments of the user base. For example, users' age, income, and household size had a weaker influence on private car ownership decisions in the second survey wave than in the first. This finding is particularly noteworthy because previous research has documented pronounced sociodemographic selectivity not only in carsharing adoption itself but also in the relationship between carsharing use and private car ownership. Several studies suggest, for example, that older individuals and those with lower incomes are more likely to forgo private car ownership in favor of carsharing (Ko et al., 2019; Le Vine & Polak, 2019; Ye et al., 2021), whereas larger households, particularly those with children, are more likely to retain private car ownership despite using carsharing (Giesel & Nobis, 2016; Namazu & Dowlatabadi, 2018).

2.3. Synthesis and research gaps

In summary, the existing literature suggests that the continued diffusion of carsharing is accompanied by an increasingly diverse user base. While early adopters largely exhibited the classic characteristics of innovation-oriented population groups, more recent studies indicate that carsharing is reaching older individuals, families, and other population groups that were previously underrepresented.

Much less is known, however, about the implications of this changing user base for the mobility-related impacts of carsharing. On the one hand, previous research has shown that both carsharing adoption itself and the relationship between carsharing use and private car ownership are characterized by pronounced sociodemographic selectivity. On the other hand, the literature suggests that, as carsharing services become more established, a larger and more diverse share of users may be willing to forgo private car ownership. Consequently, changes in the composition of the user base are also likely to reshape the mobility-related impacts of carsharing. However, the empirical evidence remains limited and partly inconsistent.

Further research is therefore needed to jointly examine how increasing market penetration affects both the composition of the carsharing user base and the relationship between carsharing use and private car ownership. Particularly valuable in this regard are empirical studies of mature carsharing systems that have clearly progressed beyond the early adopter phase and include a substantial share of later adopters. In Hamburg, the study area of the present research, the share of carsharing users among all adult holders of a driver's license reached 24 % citywide in 2023/2024 and as much as 35 % in the city center. These figures indicate that the local carsharing system has already undergone a substantial transition from a niche innovation to a mainstream mobility option.

3. Methods and data

3.1. Study area and data sets

The data used in this article are drawn from the Mobility in Germany (Mobilität in Deutschland, MiD) study, a series of surveys conducted every few years on behalf of the German Federal Ministry of Transport to collect representative data on mobility behavior in Germany and its development over time. Nobis & Kuhnimhof (2018) and Belz et al. (2025) provide detailed information on the background, content, and methodological design of these surveys. Because the MiD surveys are primarily designed to produce nationally representative findings, the size of the core sample does not permit analyses at the level of smaller spatial units, such as individual cities. However, regions and large cities may commission regional sample expansions to enable more spatially disaggregated analyses. The city of Hamburg made use of this option and provided the data collected there from the two most recent survey waves for the purposes of this study. As each MiD survey wave covered a two-year period, data are available for 2016/2017 and 2023/2024, with sample sizes exceeding 14,000 and 16,000 individuals, respectively (Fig. 1).

Hamburg provides a particularly suitable case for examining changes in carsharing user characteristics as market penetration increases. This is due to the city's diverse, extensive, and comparatively mature carsharing market. At the time of the first survey wave in 2016/2017, Hamburg already hosted several providers of free-floating and station-based carsharing services. By 2024, the city had approximately three carsharing vehicles per 1,000 inhabitants, placing it among the leading major German cities in this respect (Bundesverband Carsharing, 2024). Moreover, free-floating carsharing has been available in Hamburg since 2011, making it the city with the longest continuously operating service of this type.

The maturity of Hamburg's carsharing market is also reflected in the share of carsharing users. In 2016/2017, approximately 13 % of all adults holding a driver's license in Hamburg were registered with at least one carsharing service; by 2023/2024, this proportion had increased to around 24 % (Fig. 2). As expected, the share of carsharing users was considerably higher in the city center, where 35 % of all driver's license holders had at least one carsharing membership in 2023/2024. In contrast, the corresponding share in the outer city was only 17 % during the same period. This spatial disparity can be explained, first, by the fact that carsharing providers in Hamburg—as in many other cities (Groth et al., 2023; Ritter et al., 2023)—primarily concentrate their services in central urban areas. Second, previous research has shown that residents of more urbanized neighborhoods exhibit a higher propensity to use carsharing services (Giesel & Nobis, 2016; Kopp et al., 2015; Wali et al., 2025; Witte et al., 2024).

Unfortunately, only the second survey wave collected detailed information on whether carsharing users were registered with free-floating or station-based services. In 2023/2024, 84 % of users were registered exclusively with free-floating carsharing, 7 % exclusively with station-based carsharing, and the remaining 10 % with both service types. As no directly comparable data are available from the 2016/2017 MiD survey, findings from a survey conducted in 2019 among carsharing users in Hamburg's city center provide a useful point of comparison. According to that study, 70 % of respondents used only free-floating carsharing, 8 % only station-based carsharing, and 22 % used both variants (Czarnetzki, 2025). However, these data were collected in the vicinity of mobility hubs where vehicles from both carsharing variants were available, which is likely to explain the comparatively high share of respondents using both free-floating and station-based services. Nevertheless, the comparison suggests that free-floating carsharing has been the dominant form of carsharing in Hamburg for several years. This pattern is also consistent with the broader development of the German carsharing market: although providers of free-floating carsharing largely restrict their services to a small number of major cities, they nevertheless account for the majority of carsharing members nationwide (Bundesverband Carsharing, 2026).

3.2. Data preparation and analysis

The data sets used in this study had already undergone extensive data cleaning before being made available and were therefore ready for analysis. However, only subsets of the original samples were relevant to the research objectives of this study, requiring additional data preparation (Fig. 1). Because the analysis focuses on the determinants of carsharing use, it was restricted to individuals who were either carsharing users at the time of the survey or potentially eligible to become

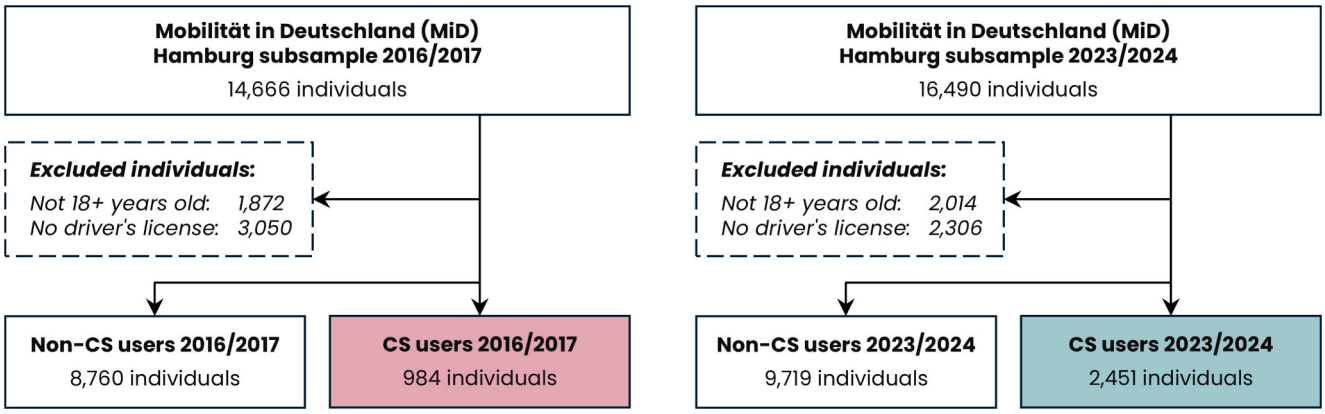

Fig. 1. Data sets and data preparation process.

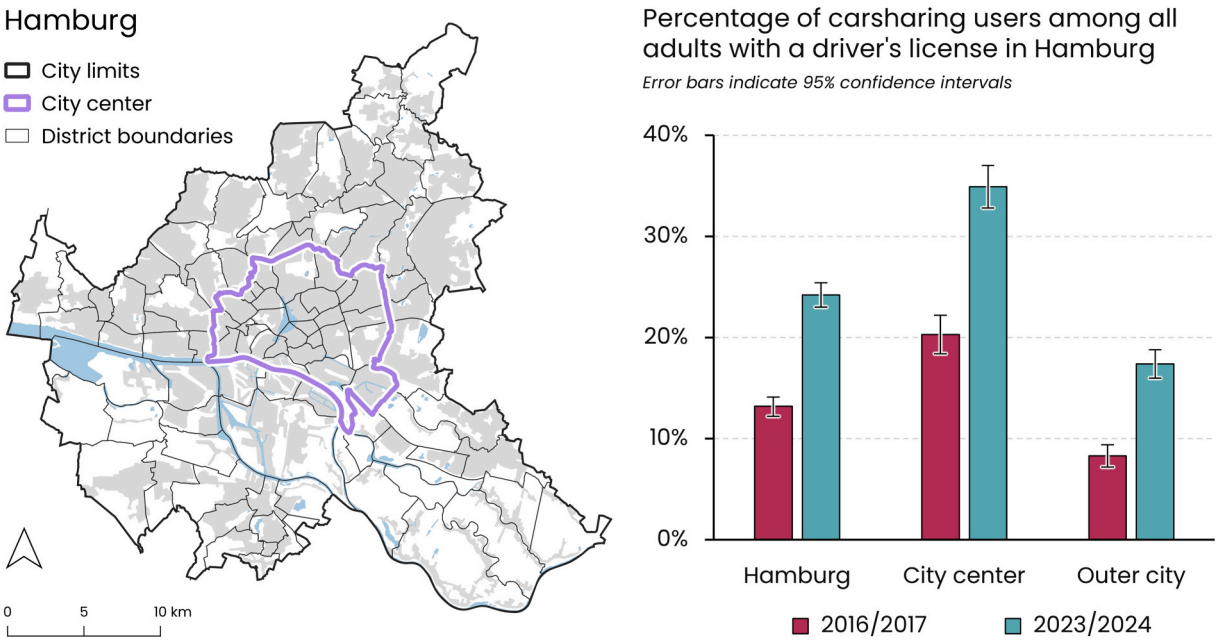

Fig. 2. Study area and carsharing adoption in Hamburg in 2016/2017 and 2023/2024. The city center is defined according to the official definition used by the City of Hamburg (Follmer et al., 2020). The percentages of carsharing users were calculated using the MiD data sets.

users.

Accordingly, all respondents younger than 18 years were excluded, as they were not eligible to register for carsharing services. To further improve the comparability between carsharing users and non-users, adults without a driver's license were also excluded, as they lacked a fundamental prerequisite for carsharing use.

The remaining respondents were then classified as either carsharing users or non-users. The definition of a carsharing user was intentionally broad: all individuals who were registered with at least one carsharing service at the time of the survey were classified as carsharing users, regardless of their actual frequency of use. The rationale for this approach was to examine which population groups were represented among carsharing members at different stages of market penetration rather than to focus exclusively on adopters who had become regular or frequent users. Sensitivity analyses (not reported in detail here) applied more restrictive definitions of carsharing users, requiring use at least several times per year or at least once per month. These analyses yielded no substantive differences from the findings reported in this article.

All statistical analyses were conducted using R 4.5 (R Core Team, 2025). Statistical significance was assessed using a conventional significance level of $p < 0.05$. To improve the generalizability of the findings, survey weights were applied throughout all analyses. These weights were already included in the data sets provided for this study.

4. Results

The results are presented in four parts. First, the study examines how the sociodemographic profile of carsharing users in Hamburg changed between the 2016/2017 and 2023/2024 survey waves and whether the user base became more diverse (Section 4.1). It then compares the sociodemographic characteristics of carsharing users in both survey waves with those of non-users to assess whether the two groups became more similar as carsharing services became more established (Section 4.2). Taken together, these first two subsections contribute to the discussion of whether the diffusion of carsharing is associated with more equitable access to this mobility option.

The third part of the results examines changes in the travel behavior of carsharing users, with a particular focus on potential shifts in mode choice and mobility profiles (Section 4.3). Finally, private car ownership among carsharing users is analyzed, including both potential changes in its prevalence and changes over time in its relationship with users' sociodemographic characteristics (Section 4.4). These final two

subsections provide insights into the potentially evolving role of carsharing in shaping travel behavior and private car ownership, while also examining the extent to which its association with private car ownership varies across users with different sociodemographic characteristics. Together, they link the perspectives of sustainable mobility and transport equity.

4.1. Sociodemographic profiles of carsharing users across survey waves

Table 1 presents the sociodemographic characteristics of carsharing users in Hamburg during the 2016/2017 and 2023/2024 survey periods. A more comprehensive overview, including the characteristics of non-carsharing users, is provided in Appendix A Table A2.

Consistent with previous research, carsharing users in the first survey wave closely matched the profile of early adopters. The majority were male, middle-aged (i.e., between 30 and 49 years old), employed, and highly educated. Most lived in small, predominantly childless households in central Hamburg and reported relatively high incomes.

Contrary to expectations, however, this profile had changed only marginally by the second survey wave. The descriptive statistics did suggest a modest shift toward a more diverse user base. For example, the data for 2023/2024 indicated higher proportions of women, older individuals (i.e., aged 50 and older), and persons with lower levels of educational attainment. There were also indications of increasing shares of larger households, households with children, and households located in the outer city. However, most of these differences amounted to only a few percentage points and were therefore too small to reach statistical significance, despite the substantial sample size and the correspondingly high statistical power.

The only statistically significant change in the sociodemographic characteristics of carsharing users concerned the socioeconomic status of their households, which was significantly higher in the second survey wave. This finding is most likely attributable to inflationary effects. Socioeconomic status was derived from household composition and net household income, and it is plausible that rising income levels shifted larger shares of respondents into higher status categories. A similar pattern was observed among non-carsharing users, where the proportion of households with a high or very high socioeconomic status increased from 38 % to 51 % between the two survey waves.

Overall, the findings indicate that the sociodemographic composition of carsharing users in Hamburg remained remarkably stable between 2016/2017 and 2023/2024. Although the later survey wave showed some indications of a broader and more diverse user base, these changes were generally small and rarely reached statistical significance. Consequently, the profile of carsharing users continued to closely resemble that typically associated with early adopters.

Table 1
Characteristics of carsharing users in Hamburg in 2016/2017 and 2023/2024. The statistical significance of differences between the two periods was assessed using weighted chi-squared tests.

Variable	Category	Characteristics of carsharing users (%)		Significance of differences
		2016/2017	2023/2024	
Gender	Female or non-binary	36.3	37.7	$p = 0.552$
	Male	63.7	62.4	
Age group	18–29 years	24.9	25.5	$p = 0.235$
	30–49 years	59.4	55.7	
	50–69 years	14.7	18.0	
	70 + years	1.0	0.9	
Main occupation	In education	4.1	7.6	$p = 0.063$
	Working	87.8	84.9	
	Retired	1.8	1.8	
	Other	6.3	5.8	
Educational level	≤ Lower secondary	11.2	15.0	$p = 0.112$
	Upper secondary	23.4	22.2	
	Higher education	65.4	62.7	
Household size	1 person	30.5	31.4	$p = 0.133$
	2 persons	34.0	29.5	
	3 + persons	35.6	39.1	
Household with minor(s)	Yes	31.5	33.8	$p = 0.345$
	No	68.6	66.2	
Socioeconomic status	Low or very low	9.6	7.4	$p < 0.001$
	Medium	30.7	22.0	
	High or very high	59.6	70.7	
Place of residence	City center	60.3	57.4	$p = 0.260$
	Outer city	39.7	42.6	

4.2. Sociodemographic differences between carsharing users and non-users across survey waves

In addition to the changes in carsharing user characteristics discussed in **Section 4.1**, this study also examined whether the sociodemographic differences between carsharing users and non-users changed over time. The underlying assumption was that, as carsharing became more widespread, carsharing users in Hamburg might have become more similar to the general population, thereby reducing the importance of sociodemographic characteristics in distinguishing users from non-users. To test this assumption, a weighted logistic regression analysis was conducted using a pooled data set from the 2016/2017 and 2023/2024 survey waves.

The dependent variable indicated whether respondents were carsharing users at the time of the respective survey (1 = yes, 0 = no). Predictor variables comprised the respondents' demographic and socioeconomic characteristics, and their place of residence within Hamburg (i.e., city center or outer city). Variables related to car ownership and travel behavior were excluded from the analyses because they are likely influenced by carsharing use itself and, given the cross-sectional nature of the data, would not permit a reliable distinction between cause and effect.

For each predictor variable, the regression model (Table 2) estimated both a main effect (B) and an interaction effect (ΔB) between the predictor and the survey period (1 = 2023/2024, 0 = 2016/2017). The full model specification is provided in Appendix **Eq. (A.1)**. The main effects represent the relationships between the predictors and the odds of being a carsharing user in the first survey wave ("baseline effects"), that is, their contribution to distinguishing carsharing users from non-users in 2016/2017. The interaction effects indicate whether and how these relationships changed by the second survey wave ("change in effects"). Reference categories were chosen to reflect characteristics that have traditionally been associated with carsharing users, such as male gender, higher educational attainment, and residence in the city center.

As expected, the baseline effects for almost all predictor variables were statistically significant and, in most cases, substantial. In 2016/2017, women, individuals aged 50 years and older, those in education or retirement, and respondents with lower levels of educational attainment had significantly lower odds of being carsharing users. The same applied to individuals living in households with three or more members, households without a high socioeconomic status, and households located in the outer city.

More surprising, however, was the finding that the interaction effects indicated almost no significant changes in these relationships by 2023/2024. Although most interaction coefficients pointed in the expected direction—namely, toward a weakening of the negative effects observed in 2016/2017—these changes were generally not statistically significant. The only exception was enrollment in education, which no longer reduced the odds of being a carsharing user in the second survey wave. By contrast, the negative effect of low socioeconomic status appeared to

Table 2
Logistic regression analysis of the influence of sociodemographic characteristics and place of residence on the odds of being a carsharing user in Hamburg. The table reports baseline effects for 2016/2017 and changes in effects by 2023/2024.

Predictor	Category	Baseline effects in 2016/2017			Change in effects by 2023/2024	
		B	OR	p	ΔB	p
Intercept	–	0.13	1.14	0.545	–	–
Gender	Female or non-binary	−0.77	0.46	< 0.001	0.07	0.578
	Male (RC)	–	–	–	–	–
Age group	18–29 years	0.38	1.47	0.018	0.07	0.744
	30–49 years (RC)	–	–	–	–	–
	50–69 years	−0.88	0.41	< 0.001	0.08	0.587
	70 + years	−1.70	0.18	< 0.001	−0.57	0.301
Main occupation	In education	−1.13	0.32	< 0.001	1.35	< 0.001
	Working (RC)	–	–	–	–	–
	Retired	−1.52	0.22	< 0.001	0.58	0.176
	Other	−0.34	0.71	0.130	0.15	0.616
Educational level	≤ Lower secondary	−1.10	0.33	< 0.001	0.36	0.092
	Upper secondary	−0.04	0.96	0.758	−0.10	0.523
	Higher education (RC)	–	–	–	–	–
Household size	1 person	0.16	1.17	0.182	−0.13	0.399
	2 persons (RC)	–	–	–	–	–
	3 + persons	−0.55	0.58	0.004	0.23	0.338
Household with minor(s)	Yes	−0.34	0.72	0.105	0.18	0.493
	No (RC)	–	–	–	–	–
Socioeconomic status	Low or very low	−0.44	0.65	0.042	−0.58	0.032
	Medium	−0.50	0.61	< 0.001	0.19	0.196
	High or very high (RC)	–	–	–	–	–
Place of residence	City center (RC)	–	–	–	–	–
	Outer city	−0.63	0.53	< 0.001	0.13	0.304
Complete cases	**20,196**					

Abbreviations: RC = Reference category; OR = Odds ratio. Dependent variable: 1 = Carsharing user, 0 = Non-user.

have become stronger. As discussed in **Section 4.1**, however, the comparability of this variable across survey waves may be limited.

Beyond examining the individual effects of the predictor variables, the analysis also assessed whether their combined ability to distinguish carsharing users from non-users declined as carsharing market penetration increased. To this end, two separate weighted logistic regression models were estimated for the 2016/2017 and 2023/2024 survey periods using the full set of predictor variables listed in Table 2. Based on these models, two receiver operating characteristic (ROC) curves were generated (Fig. 3). The ROC curves illustrate how much better the regression models perform at classifying respondents as carsharing users or non-users than random classification. A larger area under the ROC curve (AUROC) indicates greater classification accuracy.

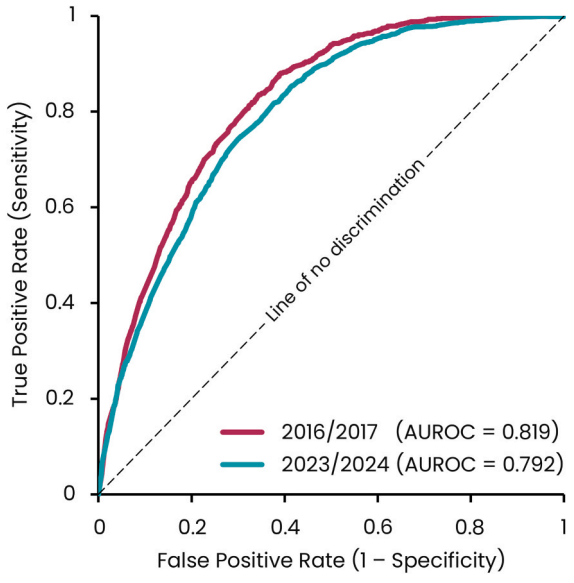

Fig. 3. Receiver operating characteristic (ROC) curves for distinguishing between carsharing users and non-users in 2016/2017 and 2023/2024 based on the predictor variables shown in Table 2. AUROC = area under the ROC curve.

The comparison of the ROC curves showed that the combined discriminatory performance of the predictor variables declined only slightly in the second survey wave (ΔAUROC = − 0.027, $p < 0.001$). According to commonly used benchmarks (Hosmer et al., 2013), the combination of sociodemographic characteristics and place of residence provided good discrimination between carsharing users and non-users in both 2016/2017 (AUROC = 0.819) and 2023/2024 (AUROC = 0.792), indicating a consistently high level of classification accuracy. Overall, the findings do not support the assumption that increasing carsharing market penetration was associated with a substantial convergence between carsharing users and the general population.

4.3. Travel behavior of carsharing users across survey waves

Fig. 4 shows the frequency of use of different travel modes among carsharing users based on their responses in the two survey waves. Appendix Table A3 provides a more detailed overview that also includes the responses of non-users.

The comparison of travel mode use among carsharing users across the two survey periods indicated only minor changes in travel behavior. For private car use, no statistically significant differences were observed between the survey waves. Notably, the share of carsharing users reporting weekly to daily private car use remained virtually unchanged (43 % in 2016/2017 and 45 % in 2023/2024), whereas the corresponding share among non-carsharing users declined from 63 % to 57 %, although it remained substantially higher overall, as expected.

A different pattern emerged for public transit use. Among carsharing users, the frequency of public transit use declined over time. However, this trend mirrors the overall decline in daily public transit use observed in Hamburg and can largely be explained by the increased prevalence of working from home following the COVID-19 pandemic (Henninger et al., 2023). Accordingly, the share of carsharing users reporting daily or near-daily public transit use decreased from 38 % in 2016/2017 to 30 % in 2023/2024. Although non-carsharing users used public

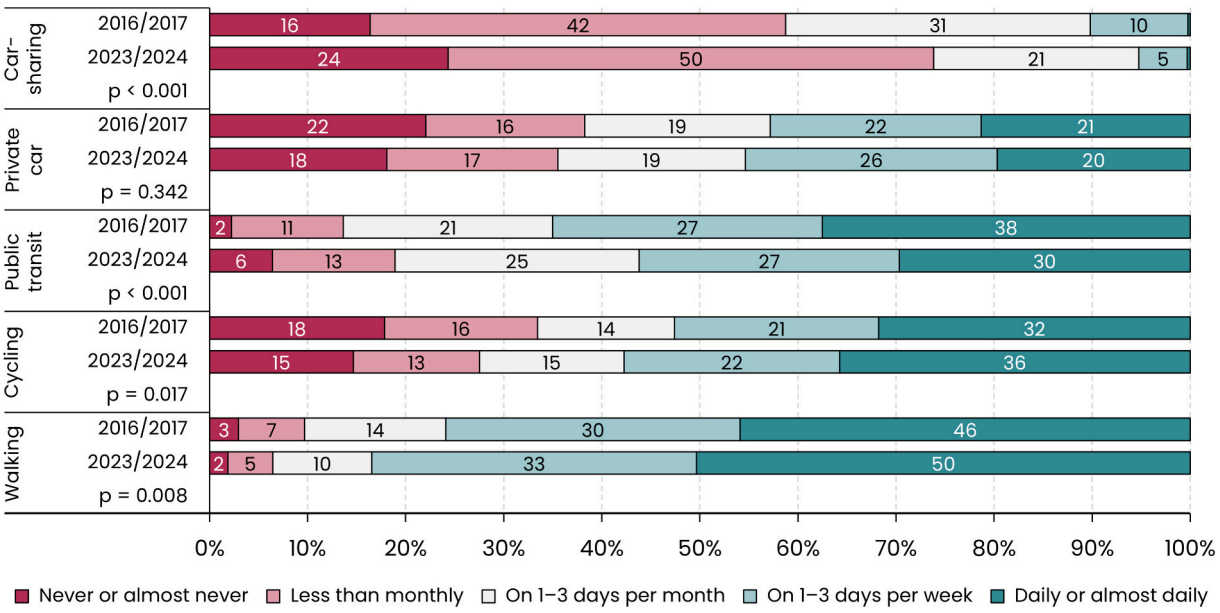

Fig. 4. Frequency of use of different travel modes by carsharing users in Hamburg in 2016/2017 and 2023/2024. Walking refers to trips made entirely on foot. The statistical significance of differences between the two periods was assessed using weighted Mann–Whitney U tests.

transit less frequently in both survey waves, they exhibited a similarly pronounced decline in daily or near-daily use (from 28 % to 22 %).

For active travel modes, the pattern differed. Among carsharing users, the share of individuals using a bicycle at least weekly increased from 53 % to 58 %, whereas it remained virtually unchanged among non-users at a lower level (42 % in 2016/2017 and 41 % in 2023/2024). A similar development was observed for walking. Among carsharing users, the proportion of respondents making trips exclusively on foot at least once a week increased from 76 % to 83 %, while the corresponding shares among non-users remained largely stable (74 % and 76 %, respectively).

The most pronounced change in the travel behavior of carsharing users concerned carsharing use itself. The frequency of carsharing use was substantially lower in the second survey wave, with the share of respondents reporting that they practically never used their carsharing membership increasing from 16 % to 24 %. A plausible explanation is that, as carsharing services matured, the number of members who no longer actively used carsharing but did not formally terminate their membership also increased.

To provide a more comprehensive assessment of potential changes in travel behavior, the analysis also examined the distribution of monomodal and multimodal mobility profiles across both survey waves. Respondents were classified as multimodal if they used at least two of the three main travel modes—car, bicycle, and public transit—during a typical week. Car use included both private vehicles and carsharing vehicles. Individuals who typically used none of these three modes during a given week—for example, because they traveled exclusively on foot or had generally low levels of mobility—were classified as “other.”.

Fig. 5 presents the distribution of monomodal and multimodal mobility profiles among carsharing users in both survey waves; a more

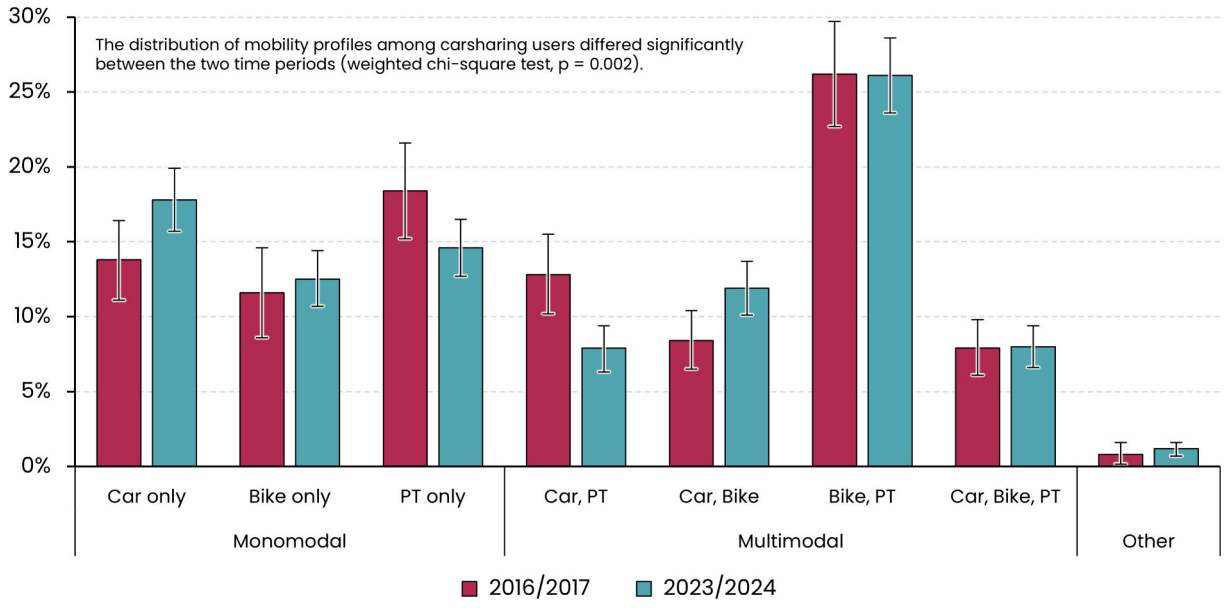

Fig. 5. Distribution of different mobility profiles among carsharing users in Hamburg in 2016/2017 and 2023/2024. Error bars indicate 95 % confidence intervals. PT = Public transit.

detailed overview for both carsharing users and non-users is provided in Appendix Table A3. Overall, the share of respondents exhibiting multimodal travel behavior remained remarkably stable among carsharing users (43 % in 2016/2017 and 45 % in 2023/2024), whereas it declined among non-users from 47 % to 41 %. Despite this overall stability, statistically significant changes were observed in the composition of both monomodal and multimodal mobility profiles among carsharing users. Specifically, mobility profiles that included or relied exclusively on public transit tended to stagnate or decline, whereas those involving cycling or car use became more prevalent. Notably, the most common mobility profile among carsharing users, accounting for approximately 26 % of respondents in both survey waves, combined at least weekly bicycle and public transit use without any car use, and consequently without carsharing use. At the same time, the share of carsharing users who relied exclusively on the car during a typical week increased slightly from 14 % to 18 %. Among non-users, by contrast, the proportion of monomodal car users remained constant at 28 % in both survey waves, albeit at a consistently higher level than among carsharing users.

In sum, the findings provide little evidence of substantial changes in the travel behavior of carsharing users as carsharing became more widespread. The observed shifts in mode choice and mobility profiles were limited in magnitude and appear to reflect both broader societal trends, such as the decline in public transit use following the COVID-19 pandemic, and developments more specific to carsharing users, including increasing levels of cycling and walking.

4.4. Car ownership and sociodemographic selectivity among carsharing users across survey waves

Table 3 compares household car ownership among carsharing users across the two survey waves. The corresponding figures for non-users are reported in Appendix Table A3. Overall, household car ownership among carsharing users remained stable across the two survey periods. Although the share of car-free households was substantially higher among carsharing users than among non-users with a driver's license in both 2016/2017 (46 % vs. 26 %) and 2023/2024 (44 % vs. 28 %), this difference did not change significantly over time.

As expected, household car ownership was strongly associated with the type of carsharing service used. In the 2023/2024 survey wave, only 41 % of respondents who exclusively used free-floating carsharing lived in car-free households. Among respondents who relied exclusively on station-based carsharing or used both service types, the corresponding shares were considerably higher, at 64 % and 57 %, respectively. At the same time, exclusive users of free-floating carsharing accounted for 84 % of all carsharing users, meaning that a slight majority of carsharing users overall still lived in households that owned at least one private car. Because the 2016/2017 survey did not collect information on the type of carsharing service used, no comparison over time was possible.

Beyond overall levels of car ownership among carsharing users, the analysis also examined whether the sociodemographic differences between users with and without private car ownership changed over time. The underlying assumption was that, as carsharing evolved from a niche innovation into a mainstream mobility option, not only carsharing adoption itself but also its association with private car ownership might become less socio-demographically selective, with a broader and more diverse range of users choosing to forgo private car ownership.

Table 3
Household car ownership of carsharing users in Hamburg in 2016/2017 and 2023/2024. The statistical significance of the difference between the two periods was assessed using a weighted chi-squared test.

Variable	Category	Car ownership of carsharing users (%)		Significance of differences
		2016/2017	2023/2024	
Household car ownership	No car	45.9	44.1	$p = 0.377$
	1 car	42.9	42.5	
	2 + cars	11.2	13.4	

To examine this question, a second logistic regression analysis was conducted. The analytical approach largely followed the methodology described in **Section 4.2** for examining the relationship between sociodemographic characteristics and carsharing use. However, the analysis in the present section was restricted to the pooled sample of carsharing users from both survey waves, and the binary dependent variable no longer distinguished between carsharing users and non-users but instead indicated whether carsharing users lived in a car-free household at the time of the survey (1 = yes, 0 = no). Descriptive statistics comparing the sociodemographic profiles of carsharing users with and without private car ownership are provided in Appendix Table A3.

As in the regression model presented in **Section 4.2**, the current model (Table 4) estimated both main effects (B) and interaction effects (ΔB). The main effects represent the relationships between the sociodemographic characteristics of carsharing users and their status as car owners or non-owners in the first survey wave (2016/2017), whereas the interaction effects indicate how these relationships changed by the second survey wave (2023/2024). To ensure comparability, the same predictor variables and category definitions as those used in **Section 4.2** were applied.

The estimated main effects revealed several statistically significant associations between the sociodemographic characteristics of carsharing users and private car ownership in the first survey wave. Carsharing users aged 50 to 69 years, those living in single-person households, and those with average or lower socioeconomic status were significantly more likely to live in car-free households in 2016/2017. By far the strongest association was observed for low or very low socioeconomic status. Compared with users with high or very high socioeconomic status, respondents in this category had approximately 8.3 times higher odds of living in a household without a private car.

Conversely, the presence of at least one child in the household and residence in the outer city were both associated with significantly higher odds of owning at least one private car. By contrast, respondents' gender, educational attainment, and employment status appeared to have no substantial influence on private car ownership.

The interaction effects indicated that several variables identified as important predictors in the first survey wave had changed substantially by the second survey wave. In particular, the initially positive effects of being aged 50 to 69 years and living in a single-person household weakened considerably over time and no longer contributed significantly to distinguishing between car-free and car-owning carsharing users in the second survey wave. Likewise, the presence of children in the household, which had exerted a significant negative effect in the first survey wave, was no longer a significant predictor in the second. By contrast, no fundamental changes were observed for the effects of low to medium socioeconomic status or residence in the outer city. Although the interaction coefficients for these variables also pointed toward weaker effects in the second survey wave, these changes were not statistically significant. According to the model estimates, no predictor was statistically significant exclusively in the second survey wave.

Finally, the analysis examined how the overall ability of the complete set of sociodemographic variables and place of residence to distinguish between carsharing users with and without private car ownership changed over time. Following the procedure described in **Section 4.2**, two separate logistic regression models were estimated for the 2016/2017 and 2023/2024 survey periods using the predictor variables listed in Table 4. Receiver operating characteristic (ROC) curves were then generated for each model (Fig. 6).

A comparison of the ROC curves showed that the combined discriminatory performance of the predictors declined substantially between the two survey waves ($\Delta AUROC = -0.065$, $p < 0.001$). Interpreted against commonly used benchmarks (Hosmer et al., 2013), the predictor set achieved acceptable discrimination between carsharing

Table 4
Logistic regression analysis of the influence of sociodemographic characteristics and place of residence on the odds of carsharing users in Hamburg living in a car-free household. The table reports baseline effects for 2016/2017 and changes in effects by 2023/2024.

Predictor	Category	Baseline effects in 2016/2017			Change in effects by 2023/2024	
		B	OR	p	ΔB	p
Intercept	–	−1.32	0.27	0.003	–	–
Gender	Female or non-binary	0.05	1.05	0.790	−0.04	0.858
	Male (RC)	–	–	–	–	–
Age group	18–29 years	0.31	1.36	0.212	−0.37	0.232
	30–49 years (RC)	–	–	–	–	–
	50–69 years	0.56	1.76	0.015	−0.80	< 0.001
	70 + years	−0.01	0.99	0.985	−0.29	0.734
Main occupation	In education	−0.57	0.56	0.315	0.59	0.364
	Working (RC)	–	–	–	–	–
	Retired	−0.11	0.89	0.818	−0.11	0.879
	Other	0.81	2.25	0.068	−0.93	0.091
Educational level	≤ Lower secondary	−0.34	0.72	0.278	−0.47	0.236
	Upper secondary	−0.39	0.68	0.086	0.12	0.655
	Higher education (RC)	–	–	–	–	–
Household size	1 person	0.81	2.24	< 0.001	−0.52	0.049
	2 persons (RC)	–	–	–	–	–
	3 + persons	−0.41	0.66	0.317	0.23	0.642
Household with minor(s)	Yes	−1.02	0.36	0.019	1.10	0.038
	No (RC)	–	–	–	–	–
Socioeconomic status	Low or very low	2.12	8.29	< 0.001	−0.51	0.404
	Medium	0.63	1.88	0.002	0.10	0.719
	High or very high (RC)	–	–	–	–	–
Place of residence	City center (RC)	–	–	–	–	–
	Outer city	−0.64	0.53	< 0.001	0.13	0.560
Complete cases	**3,170**					

Abbreviations: RC = Reference category; OR = Odds ratio. Dependent variable: 1 = Car-less carsharing user, 0 = Car-owning carsharing user.

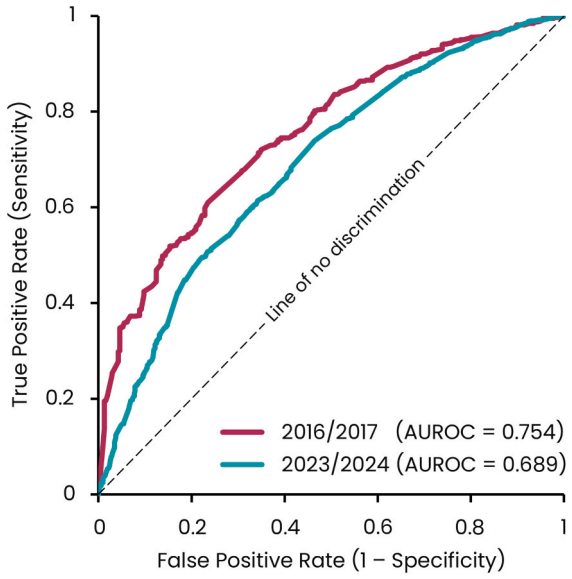

Fig. 6. Receiver operating characteristic (ROC) curves for distinguishing between carsharing users with and without car ownership in 2016/2017 and 2023/2024 based on the predictor variables shown in Table 4. AUROC = Area under the ROC curve.

users with and without private car ownership in 2016/2017 (AUROC = 0.754). By 2023/2024, however, its discriminatory performance had declined to a rather poor level (AUROC = 0.689). Taken together, these findings suggest that, although the prevalence of private car ownership among carsharing users remained largely unchanged as carsharing became more widespread, the propensity to forgo private car ownership became less socio-demographically selective and extended to a broader range of sociodemographic groups.

5. Discussion and conclusion

5.1. Summary and discussion of key findings

The question of who carsharing users are and how they differ from non-users has been a recurring theme in the literature. Because carsharing remained a niche offering for a long period—and continues to do so in many contexts—a large share of the existing evidence is based on studies of early adopters. By contrast, relatively little is known about the users and mobility impacts of more established carsharing systems that have progressed beyond the early adopter phase. Such knowledge is highly relevant for policymakers, transport planners, and carsharing operators, as it remains unclear to what extent findings derived from early adopters can be generalized to later generations of users.

Owing to its comparatively advanced level of market penetration, Hamburg provides a particularly suitable case for examining users of a mature carsharing system. Accordingly, this study investigated how the characteristics, travel behavior, and car ownership of the city's carsharing users evolved over time using repeated cross-sectional surveys based on independent samples collected during two periods: the early adopter phase (2016/2017) and a later stage of market diffusion (2023/2024). Beyond comparing carsharing users across the two periods, the study also examined whether the sociodemographic composition of carsharing users became more similar to that of non-users over time and whether the sociodemographic differences between carsharing users with and without private car ownership became less pronounced. In doing so, the study not only traced changes in the citywide population of carsharing users but also assessed whether carsharing adoption and its association with private car ownership became less socio-demographically selective as market penetration increased.

The findings indicate that the profile of carsharing users changed only marginally over time, despite the nearly decade-long interval between the surveys and the substantial increase in citywide carsharing adoption—from 13 % to 24 % of all adult driver's license holders. In both survey periods, carsharing users were predominantly male, young or middle-aged, highly educated, and comparatively affluent, and they

tended to live in smaller, mostly childless households located in the city center. Although the results pointed to a modest shift away from the classic profile of early adopters and toward greater similarity between users and non-users, this convergence remained limited. Overall, carsharing users in Hamburg continued to differ markedly from the general population in sociodemographic terms. According to the Diffusion of Innovations theory (Rogers, 2003), the composition of the user base should gradually diversify as diffusion progresses, and previous empirical studies largely support this expectation (Haustein, 2021; Hjorteset, 2024; Witte et al., 2024; Xu et al., 2024). While the present study likewise identified evidence of such a trend, the observed changes were considerably weaker than expected.

Similarly, no substantial changes were observed in either the travel behavior or the levels of private car ownership among carsharing users. In both survey periods, a majority of respondents continued to own at least one private car (54 % and 56 %, respectively). At the same time, car-free households consistently accounted for a substantially larger share of carsharing users than of non-users with a driver's license (46 % versus 26 % in 2016/2017 and 44 % versus 28 % in 2023/2024). A similar pattern emerged for private car use: in both survey periods, carsharing users reported using private cars considerably less frequently than non-users, but this difference likewise remained largely unchanged over time. Taken together, these findings are consistent with the broader body of research showing that individuals with car-free or car-reduced lifestyles are overrepresented among carsharing users, although the cross-sectional nature of the data used in this study does not allow the observed differences to be disentangled into self-selection effects and causal effects of carsharing. Unlike the repeated cross-sectional study of station-based carsharing users in Seoul by Kim et al. (2019), however, the association between carsharing use and living without a private car did not appear to strengthen in Hamburg as the carsharing system matured.

One possible explanation lies in the distribution of users across different carsharing models. In the second survey wave, 84 % of respondents reported using free-floating carsharing (FFCS) exclusively, while a further 10 % used both free-floating and station-based carsharing (SBCS). This distribution is consistent with the overall structure of the German carsharing market, where FFCS dominates membership in major cities. At the same time, the predominance of FFCS may limit the extent to which carsharing becomes socio-demographically inclusive and substitutes for private car ownership. On the one hand, previous research has shown that FFCS users are less diverse than SBCS users, as FFCS disproportionately attracts men, younger individuals, and higher-income groups (Becker et al., 2017; Giesel & Nobis, 2016; Namazu et al., 2018; Ramos et al., 2023). The findings of the present study suggest that these patterns remain largely stable even as market penetration increases. On the other hand, FFCS has consistently been found to exert weaker effects on private car ownership than SBCS (Becker et al., 2017; Chicco et al., 2022; Lempert et al., 2019; Namazu & Dowlatabadi, 2018), which has been attributed to the lower reliability and predictability of free-floating services compared with station-based systems (Becker et al., 2018; Glotz-Richter, 2016).

Against this background, persistent private car ownership among a substantial share of carsharing users may constitute a limiting factor for the positive system-wide impacts of carsharing. Existing studies suggest that carsharing is most effective in reducing car use and greenhouse gas emissions when it substitutes for private car ownership; however, when users retain access to a private car, carsharing is more likely to complement rather than replace private car use and may, in some cases, even contribute to increases in overall vehicle kilometers traveled (Martin & Shaheen, 2011a; Nijland & van Meerkerk, 2017; Vejchodská et al., 2024).

A further concern is that the population groups that remain underrepresented among carsharing users in Hamburg are precisely those for whom carsharing appears to have the greatest potential to reduce private car ownership. Previous studies have shown, for example, that older users are more likely to give up their private cars (Ko et al., 2019; Van der Linden et al., 2025; Witte et al., 2024; Ye et al., 2021), as are users with comparatively low incomes (Kim et al., 2019; Ko et al., 2019; Le Vine & Polak, 2019; Ye et al., 2021). The present study likewise showed that the propensity to forgo private car ownership was not distributed evenly across sociodemographic groups.

At the same time, one particularly noteworthy finding was that age and household composition appeared to lose much of their explanatory power for car ownership decisions among carsharing users over time. Whereas in 2016/2017 adults aged 50 to 69 years, single-person households, and households without children were significantly overrepresented among car-free carsharing users, by 2023/2024 the propensity to forgo private car ownership appeared to have extended to younger age groups, larger households, and households with children. A comparable pattern was reported by Kim et al. (2019) for Seoul. By contrast, no comparable decline was observed in the influence of socioeconomic status or residential location. In both survey waves, carsharing users with comparatively high socioeconomic status or those living outside the city center remained substantially more likely to retain at least one private car despite using carsharing.

Taken as a whole, the findings suggest that the diffusion of carsharing from a niche innovation to a mainstream mobility option does not necessarily lead to rapid changes in either the composition of its user base or its overall mobility impacts. Despite a substantial increase in market penetration, carsharing users in Hamburg remained clearly distinguishable from non-users in sociodemographic terms, and the prevalence of private car ownership among users remained remarkably stable. At the same time, the study provides evidence that the influence of carsharing users' sociodemographic characteristics on their propensity to forgo private car ownership has weakened, suggesting a gradual broadening of the mobility impacts of carsharing beyond specific user groups even in the absence of major changes in aggregate car ownership levels. An important consideration when interpreting these findings is that Hamburg's carsharing market—and consequently the study sample—is overwhelmingly dominated by free-floating carsharing, a service model that previous research has generally found to be less socio-demographically inclusive and less effective in reducing private car ownership than station-based systems.

5.2. *Implications for policy and practice*

The findings of this study have important implications for both transport policy and the future design of carsharing systems. Above all, they suggest that market forces alone are unlikely to make carsharing substantially more socio-demographically inclusive. Policymakers and transport planners should therefore not assume that continued growth in carsharing fleets and memberships will automatically translate into more equitable access to this mobility option. Instead, targeted measures are needed to engage population groups that remain underrepresented among carsharing users and are unlikely to be reached through market expansion alone. This is relevant not only from the perspective of transport equity but also from an environmental perspective. The relationship between income and carsharing illustrates this point: although lower-income households appear to face comparatively high barriers to adopting carsharing, those who do become users are particularly likely to forgo private car ownership.

Numerous studies have examined measures to increase the attractiveness of carsharing, many of which focus on infrastructure improvements. Among the most frequently cited are dense spatial coverage with carsharing vehicles and stations (Ko et al., 2019; Namazu et al., 2018; Paundra et al., 2017) and preferential on-street parking for carsharing vehicles (Czarnetzki, 2023; de Lorimier & El-Geneidy, 2013; Dowling & Kent, 2015; Martin et al., 2021). Likewise, integrating carsharing with public transportation and other shared mobility services—for example, through mobility hubs (Bösehans et al., 2023; Miramontes et al., 2017) or integrated booking and payment systems within Mobility-as-a-Service

platforms (Cantelmo et al., 2022; Röhrich et al., 2024)—has been shown to increase carsharing adoption.

However, expanding infrastructure alone is unlikely to be sufficient to diversify the user base. This conclusion is supported by the case of Hamburg, where an extensive and continuously expanding network of mobility hubs with dedicated carsharing parking spaces has been established (Czarnetzki & Siek, 2023; Czarnetzki et al., 2025) without being accompanied by a substantial diversification of the carsharing user base. Moreover, previous research suggests that infrastructure is particularly important for the transition from initial experiences with carsharing to regular use, whereas the decision to join a carsharing service in the first place is influenced more strongly by information, awareness, and targeted marketing measures (Wang & Song, 2024). Indeed, several studies have identified limited awareness of local carsharing opportunities as one of the principal barriers to adoption (Abouelela et al., 2026; Burghard & Scherrer, 2022; Carmen et al., 2021; Zhou et al., 2020). Consistent with this argument, an experimental study from Oslo demonstrated that directly contacting owners of older and infrequently used cars with tailored information about local carsharing options significantly increased adoption rates (Ciccone & Wangsness, 2025).

It should also be noted that profit-oriented business-to-consumer carsharing providers often have limited incentives to expand their services beyond central, relatively affluent urban areas into neighborhoods where residents do not match the typical profile of existing carsharing users (Groth et al., 2023; Ritter et al., 2023). The present study likewise revealed persistent inequalities in access to carsharing: despite the comparatively advanced diffusion of carsharing in Hamburg, lower-income households and residents of the outer city remained underrepresented among users, and carsharing users living outside the city center were substantially more likely to retain private car ownership. There is little reason to expect these disparities to diminish without targeted public-sector intervention.

The literature offers several examples of policy instruments that can actively influence both the adoption of carsharing and its mobility impacts among underrepresented population groups. For example, pilot projects in the United States have shown that subsidizing membership and usage fees for low-income households and other socially disadvantaged groups can substantially improve equitable access to carsharing (Pan et al., 2022; Paul et al., 2024; Yassine et al., 2025). For older adults, by contrast, limited digital literacy and lower levels of trust in digital technologies appear to constitute the principal barriers to adoption (Chua et al., 2025; Dill & McNeil, 2021). Targeted information campaigns, personal onboarding, and assisted registration and booking procedures therefore appear to be promising measures for increasing participation among this group.

Beyond conventional profit-oriented business-to-consumer services, cooperative carsharing models involving housing associations and residents may offer additional opportunities to reach underserved neighborhoods and population groups. Case studies from Munich (Nachtigall, et al. 2025), Greater Copenhagen (Lindberg et al., 2024), and several Swedish cities (Styre & Johansson, 2025) demonstrate that integrating carsharing into residential developments—for example, through discounted memberships for residents or resident-exclusive vehicles and stations—can reduce barriers to adoption and strengthen carsharing as an alternative to private car ownership. From a policy perspective, such initiatives could be encouraged by allowing developers to reduce minimum parking requirements when high-quality residential carsharing services are incorporated into new housing developments (Styre & Johansson, 2025).

Finally, the findings highlight the importance of distinguishing between free-floating and station-based carsharing when evaluating the impacts of carsharing and integrating it into urban mobility systems. The Hamburg carsharing market is overwhelmingly dominated by free-floating services; in 2023/2024, only 7 % of carsharing users were not registered with at least one free-floating provider. This market structure may partly explain why both the diversification of the user base and the strengthening of the association between carsharing use and car-free or car-reduced mobility patterns were less pronounced than expected. By contrast, several studies reporting stronger diversification of the user base and more pronounced changes in private car ownership over time were conducted in predominantly station-based carsharing systems (Kim et al., 2019; Witte et al., 2024; Xu et al., 2024).

At the same time, these findings should not be interpreted as an argument for favoring station-based over free-floating carsharing in transport policy. Although free-floating services in Hamburg—as in many other cities—show substantially weaker associations with giving up private car ownership than station-based systems, the exceptionally high level of market penetration observed in Hamburg was likely made possible by the widespread availability and convenience of free-floating services. Rather than viewing the two models as competing alternatives, they should be regarded as complementary components of the urban mobility system. Free-floating carsharing appears particularly effective at attracting new users, whereas station-based carsharing appears better suited to encouraging households to forgo private car ownership. In cities where both models are available, policymakers and transport planners should therefore seek to improve the integration of these services, for example, through interoperable booking platforms, combined membership options, and coordinated information and pricing strategies. Such measures could increase not only the overall attractiveness of carsharing but also its effectiveness in reducing private car ownership, as previous research suggests that users holding memberships with multiple carsharing providers are more likely to perceive carsharing as a viable substitute for private car ownership than those relying on a single service type (Czarnetzki, 2025; Giesel & Nobis, 2016; Jochem et al., 2020; Namazu & Dowlatabadi, 2018).

CRediT authorship contribution statement

Felix Czarnetzki: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT in order to improve readability and language. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2026.102164.

Data availability

The author does not have permission to share data.

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