

Do mobility hubs boost the adoption and impact of carsharing in the urban periphery? Insights from a mixed-methods case study

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ABSTRACT

Mobility hubs represent an emerging instrument in transportation planning, with the potential to catalyze the uptake and effects of carsharing. However, extant research on the interplay between mobility hubs and carsharing is limited and has focused predominantly on highly urbanized areas. The question of how mobility hubs and carsharing interact in the urban periphery, where conditions for carsharing are considerably less favorable, remains largely unexplored in the literature. In this context, our paper seeks to answer whether mobility hubs enhance the adoption and impact of carsharing on the outskirts of a major city. Utilizing newly established mobility hubs in southern Hamburg, Germany, as a case study, our analysis draws on 14 interviews with residents living near these hubs and a survey of the local population ($n = 310$). Our findings indicate that peripheral mobility hubs have a positive influence on the adoption of carsharing and the willingness of carsharing users to forgo car ownership. This phenomenon can be attributed to the heightened visibility of carsharing services and the enhanced accessibility of carsharing vehicles and parking spaces. However, the efficacy of the mobility hubs was hindered by multiple factors, including hub-related issues (e.g., parking spaces occupied by unauthorized vehicles) and systemic deficiencies in carsharing services in peripheral areas (e.g., insufficient vehicle availability or unattractive pricing for trips across the city limits). Consequently, while mobility hubs in the urban periphery demonstrate capability in fostering carsharing, their impact remains constrained in the absence of comprehensive measures to improve carsharing offerings in these areas.

1. Introduction

Mobility hubs represent an emerging instrument in the fields of urban and transportation planning, which has gained increasing recognition in recent years, especially in major cities across Europe and North America (Arnold et al., 2023a). The extant literature reflects a variety of perspectives on the specific characteristics of mobility hubs and the various forms they can take (Geurs et al., 2024; Roukouni et al., 2023; Weustenenk and Mingardo, 2023). Typically, mobility hubs are defined as physical, non-temporary, and recognizable locations where multiple mobility options are offered together (Geurs et al., 2024). More specifically, they are often conceptualized as public transportation nodes that provide complementary services, such as carsharing, bike-sharing systems, and high-quality parking for private bikes, to facilitate intermodal transfers (Arnold et al., 2023a; Weustenenk and Mingardo, 2023). However, recent advancements have witnessed an evolution in the concept, with the introduction of smaller hubs that provide shared mobility options within residential areas, often functioning

independently of public transportation (Bösehans et al., 2023; Liao et al., 2024; Roukouni et al., 2023).

The fundamental objective of mobility hubs is to promote multimodal mobility behaviors and to establish themselves as a flexible alternative to the ownership and use of private cars (Liao et al., 2024). Consequently, carsharing services are among the most common features of mobility hubs (Arnold et al., 2023a). This is due to the particular suitability of carsharing in replacing private car ownership (Chicco et al., 2022; Ye et al., 2021) and supporting multimodal mobility patterns (Göddecke et al., 2022; Silvestri et al., 2021). However, carsharing itself can also benefit from mobility hubs through enhanced visibility of carsharing services or improved user experience due to more convenient and reliable access to carsharing vehicles and parking spaces. Indeed, previous studies suggest that the acceptance and impact of carsharing increases when provided at mobility hubs (Czarnetzki and Siek, 2023; Liao et al., 2024; Miramontes et al., 2017). However, research on the interaction between mobility hubs and carsharing remains limited. Moreover, extant findings are predominantly derived from highly

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urbanized areas, such as the central districts of major cities. Consequently, these findings may not be readily applicable to less densely populated areas, such as the urban periphery, where different demographics and spatial structures prevail.

Peripheral carsharing services and mobility hubs have received scant attention from researchers, presumably because carsharing companies—the key contributors to the implementation of mobility hubs—continue to concentrate their services primarily in urban centers and are only gradually expanding to the periphery of cities (Groth et al., 2023; Ritter et al., 2023). However, there is a need to establish shared mobility services such as carsharing outside of city centers as an alternative to private cars as well. Firstly, this necessity stems from an equity perspective, as innovative mobility services should not be exclusively available to residents of urban centers. Furthermore, the promotion of shared mobility services in peripheral areas is also recommended from an ecological perspective, as car ownership and use are generally higher among people residing in the periphery of cities than among inner-city residents (Handy et al., 2005; Leck, 2006; Naess, 2012).

Against this background, the present study aims to examine the viability of mobility hubs located in the periphery of a major city in supporting carsharing and its impact on car ownership. The empirical basis is a case study from Hamburg, the second-largest city in Germany. In the wake of several years marked by positive experiences with mobility hubs in the city center, Hamburg initiated the construction of a number of mobility hubs in its southern periphery in December 2022—an area that presents comparatively challenging conditions for carsharing.

The city of Hamburg offers a remarkably extensive array of carsharing services, encompassing both free-floating carsharing, wherein vehicles can be retrieved and parked at nearly any location within a designated service area, and round-trip carsharing, where vehicles are exclusively retrieved from specific stations and must be returned to the same stations at the conclusion of the rental period. However, as is typical for business-to-consumer carsharing (Ferrero et al., 2018; Groth et al., 2023; Ritter et al., 2023), the supply of vehicles and stations is much more extensive in the city center than on the outskirts. The mobility hubs examined were thus established with the objective of enhancing the accessibility, convenience, and reliability of carsharing services in Hamburg's urban periphery. To this end, each mobility hub was equipped with four to six dedicated carsharing parking spaces where vehicles from different providers (both free-floating and round-trip carsharing) can be rented and parked.

The introduction of mobility hubs in the southern periphery of Hamburg was the subject of a scientific evaluation, which sought to investigate the mobility-related effects of the new hubs and their carsharing offerings. Utilizing a convergent mixed-methods approach (Creswell and Clark, 2017), we conducted a series of interviews with residents living in proximity to the newly established mobility hubs as well as a survey of the local population, analyzed the two data sets separately and independently from each other, and subsequently merged the qualitative and quantitative findings to create a more comprehensive understanding of the impact of peripheral mobility hubs. We opted for the convergent mixed-methods design due to the temporal constraints imposed by the project framework, which necessitated the collection of all data concurrently. Despite these challenges, the convergent design allowed us to combine the strengths of qualitative research, such as in-depth understanding based on a small sample, with the strengths of quantitative research, including generalization to a population based on a larger sample. The two samples encompassed both users and non-users of carsharing and mobility hubs. Leveraging these data, our paper aims to answer the following two research questions:

- 1) Do peripheral mobility hubs promote the *adoption* of carsharing, that is, do they increase the interest of non-carsharing members in the urban periphery to become carsharing users?

- 2) Do peripheral mobility hubs enhance the *impact* of carsharing, that is, do they increase the willingness of carsharing members in the urban periphery to forgo car ownership?

The remainder of the paper is structured as follows: Section 2 delves deeper into the theoretical background by reviewing previous research relevant to carsharing in the urban periphery and the interaction between mobility hubs and carsharing services. Section 3 provides an overview of the study area and the methods used for collecting, processing, and analyzing the empirical data. Building on this, key findings from the interviews (Section 4) and the survey (Section 5) are presented in separate sections before being integrated and discussed in Section 6.

2. Theoretical background

2.1. Carsharing in the urban periphery

Concurrent with the global growth of business-to-consumer carsharing services and their membership numbers (Shaheen and Cohen, 2020), the past few years have also witnessed a notable increase in scientific publications concerning the acceptance and impact of carsharing. However, as carsharing companies tend to concentrate their services in the central parts of large cities (Ferrero et al., 2018; Groth et al., 2023; Ritter et al., 2023), the vast majority of past publications have also focused on such highly urbanized study areas.

Conversely, studies examining carsharing services in urban peripheries or suburban regions remain infrequent in the extant literature. Nonetheless, earlier research generally indicates that the adoption of carsharing and its impact on car ownership in these areas are constrained. For instance, in their study of carsharing in the suburbs of Melbourne, Australia, Jain et al. (2022) found that as distance from the urban center increases, carsharing is more likely to be used as a supplement to car ownership rather than as a substitute for it. A carsharing service located on the outskirts of Le Mans, France, which was the subject of a study by Leroy et al. (2023), did not succeed in attracting regular users and ultimately did not meet expectations. In a similar vein, Lindberg et al. (2024) utilized the suburbs of Copenhagen, Denmark, as a case study, demonstrating that the strong orientation of these areas toward private car ownership poses a particular challenge to the successful implementation of carsharing.

The relatively modest performance of carsharing services outside of city centers is not unexpected. A substantial body of research has demonstrated a positive correlation between the urbanity of one's place of residence and both the interest in using carsharing (e.g., Aguilera-García et al., 2022; Carmen et al., 2021; Dias et al., 2017; Giesel and Nobis, 2016; Kopp et al., 2015; Münzel et al., 2019; Prieto et al., 2017) and the propensity to replace personal vehicles with carsharing options (e.g., Clewlow, 2016; Laviolette et al., 2024; Vega-Gonzalo et al., 2024). This phenomenon can be attributed to the fact that carsharing is particularly appealing and effective in environments where spatial structures and mobility offerings generally support the decision not to own a car. For instance, prior studies found that a higher quality of public transportation has a positive effect on carsharing usage (Zu et al., 2024) and the willingness of carsharing users to forgo car ownership (Ye et al., 2021). Conversely, greater availability of parking spaces in close proximity to one's residence has been shown to have a negative effect on the usage and impact of carsharing (Ceccato and Diana, 2021; Hausteijn, 2021).

The aforementioned findings, however, should not be interpreted to suggest that carsharing services should be exclusively available in urban centers. In contrast to inner-city areas, the periphery of cities typically exhibits higher levels of car dependency, car ownership, and car use (Handy et al., 2005; Leck, 2006; Naess, 2012). On the one hand, this underscores the challenges for carsharing in such areas, since more extensive use of private cars and a stronger perception of car dependence typically diminish interest in carsharing and its effects on car

ownership (Giesel and Nobis, 2016; Haustein, 2021; Ikezoe et al., 2020; Namazu et al., 2018; Ramos and Bergstad, 2021; Vejchodská et al., 2024). On the other hand, it indicates a relatively high potential for reducing private car ownership and car use in the urban periphery, provided that carsharing can be successfully established there. In this regard, Kurisu et al. (2023) utilized the example of major Japanese cities to demonstrate that carsharing can lead to a more substantial reduction in carbon dioxide emissions in areas where private car ownership and usage are more prevalent. This can be attributed to the tendency of carsharing services in these areas to serve as substitutes for private vehicles, which are often older and less efficient, rather than as alternatives to public transportation.

2.2. Interaction between mobility hubs and carsharing

In recent years, mobility hubs have emerged as a prominent topic in academic discourse. A substantial proportion of the extant literature focuses on defining and classifying these hubs (e.g., Geurs et al., 2024; Roukouni et al., 2023; Weustenenk and Mingardo, 2023) or exploring hypothetical networks of such hubs and their implications for mobility (e.g., Anderson et al., 2017; Blad et al., 2022; Liao et al., 2024; Bösehans et al., 2023; Stadnichuk et al., 2024; Xanthopoulos et al., 2024). Conversely, research focusing on the evaluation of existing mobility hubs remains relatively limited (e.g., Czarnetzki and Siek, 2023; Miramontes et al., 2017). This discrepancy may be ascribed to the frequent neglect of comprehensive evaluations during the establishment of these hubs (Arnold et al., 2023b; Xu et al., 2025).

The primary objective of mobility hubs is to promote multimodal mobility behaviors and to decrease dependence on private car ownership. Consequently, carsharing has become a prevalent feature of these hubs (Arnold et al., 2023a). In accordance with this observation, Bösehans et al. (2023) and Liao et al. (2024) found that mobility hubs hold particular appeal for car users in European cities when they offer (electric) carsharing services.

The relationship between mobility hubs and carsharing is, however, mutually beneficial. While the acceptance of mobility hubs benefits from the provision of carsharing services, these services may in turn benefit from enhanced visibility and accessibility. A plethora of studies underscore the significance of convenient access to carsharing vehicles and parking spaces in making carsharing more appealing, particularly in comparison to personal car use (de Luca and Di Pace, 2015; Diana and Ceccato, 2022; Ko et al., 2019; Namazu et al., 2018; Paundra et al., 2017; Rotaris et al., 2019; Silvestri et al., 2021; Wang et al., 2020). Consequently, numerous researchers advocate for the provision of dedicated carsharing parking spaces in easily accessible locations (Cantelmo et al., 2022; Czarnetzki, 2023; de Lorimier and El-Geneidy, 2013; Dowling and Kent, 2015), which usually aligns well with the typical locations of mobility hubs.

In addition to accessibility and convenience, previous research emphasizes the pivotal role of promotional measures in fostering the adoption of carsharing. While easy access to carsharing vehicles and parking spaces is particularly important for converting individuals with initial carsharing experience into regular users, promotional efforts are more crucial in attracting those without prior experience in carsharing (Wang and Song, 2024). This perspective is corroborated by the findings of Zhou et al. (2020) and Carmen et al. (2021), which have identified a dearth of awareness regarding local carsharing options as a substantial impediment to initial adoption. In this context, the integration of carsharing services with prominently designed and strategically located mobility hubs presents a promising strategy to boost carsharing adoption.

Research on existing mobility hubs offering carsharing supports these considerations. For instance, Miramontes et al. (2017) found that a large mobility hub in Munich, Germany, significantly increased the appeal of carsharing, particularly as an ancillary service to public transportation. In a similar vein, Czarnetzki and Siek (2023)

demonstrated that the establishment of a network of smaller mobility hubs in Hamburg, Germany, led to an enhanced perception of carsharing as a viable alternative to private car ownership. This, in turn, resulted in a decline in car ownership among mobility hub users and a corresponding shift toward sustainable modes of transportation. However, it should be noted that both studies were conducted in city centers, and their findings may not be directly applicable to mobility hubs in more peripheral areas. To the best of our knowledge, the interaction of mobility hubs and carsharing in the urban periphery remains an under-explored research topic.

3. Methodology

3.1. Study areas

In December 2022, the city of Hamburg initiated the establishment of mobility hubs in several neighborhoods situated in the southern periphery of the city. This initiative represented an expansion of the city's existing network of mobility hubs, which had been developing since 2013 within the city center. As would be expected, Hamburg's peripheral districts exhibit a lower prevalence of carsharing memberships in comparison to the inner city, while demonstrating higher rates of car usage and ownership (Henninger et al., 2023). The establishment of new mobility hubs was thus intended to provide more equitable access to carsharing and to reduce dependency on private vehicles in the urban periphery.

Each new hub was equipped with four to six dedicated carsharing parking spaces, where vehicles from multiple carsharing companies can be rented and parked (Fig. 1). During the research period, four carsharing companies were present at the hubs. Of these, three offered free-floating carsharing and one offered round-trip carsharing. The carsharing-only parking spots were created by converting regular on-street parking spaces. The mobility hubs examined can be most appropriately classified as neighborhood mobility hubs (Rongen et al., 2022; Weustenenk and Mingardo, 2023). Such hubs are primarily designed to serve residents of the respective neighborhoods, with the objective of facilitating the beginning or conclusion of trips rather than promoting intermodal transfers within travel chains.

In order to assess the effects of the new mobility hubs, we conducted semi-structured interviews and an online survey among residents near five of these hubs from November 2023 to March 2024 (Fig. 2). Despite the existence of additional mobility hubs in the southern region of Hamburg during that period, our analysis focused exclusively on the five most established locations. This approach was chosen to provide the interviewees and survey participants with sufficient time to become aware of the new mobility hubs or even gain personal experience using them. At the onset of the data collection period, the ages of the five mobility hubs under study ranged from nine to eleven months.

To ensure the uniform definition of the study areas, we employed a GIS-based network analysis to identify all residential addresses from which at least one of the examined mobility hubs could be reached on foot within a maximum distance of approximately 400 m. Participation in the interviews or survey was exclusive to residents of these areas.

3.2. Qualitative approach

The qualitative research approach employed in this study included 14 semi-structured interviews with residents from the previously described study areas. The recruitment of interviewees was facilitated by three focus groups, which were conducted with a total of 24 participants in November 2022. In these focus groups, which took place prior to the opening of the first mobility hubs in the study areas, residents' attitudes and expectations regarding the features of the planned mobility hubs and their suitability as an alternative to private car ownership were explored. The findings from these focus groups have been previously published (Czarnetzki et al., 2024) and will not be



Fig. 1. Carsharing vehicles offered by different companies at one of the mobility hubs in the southern periphery of Hamburg, Germany.
Source: Authors' own photo

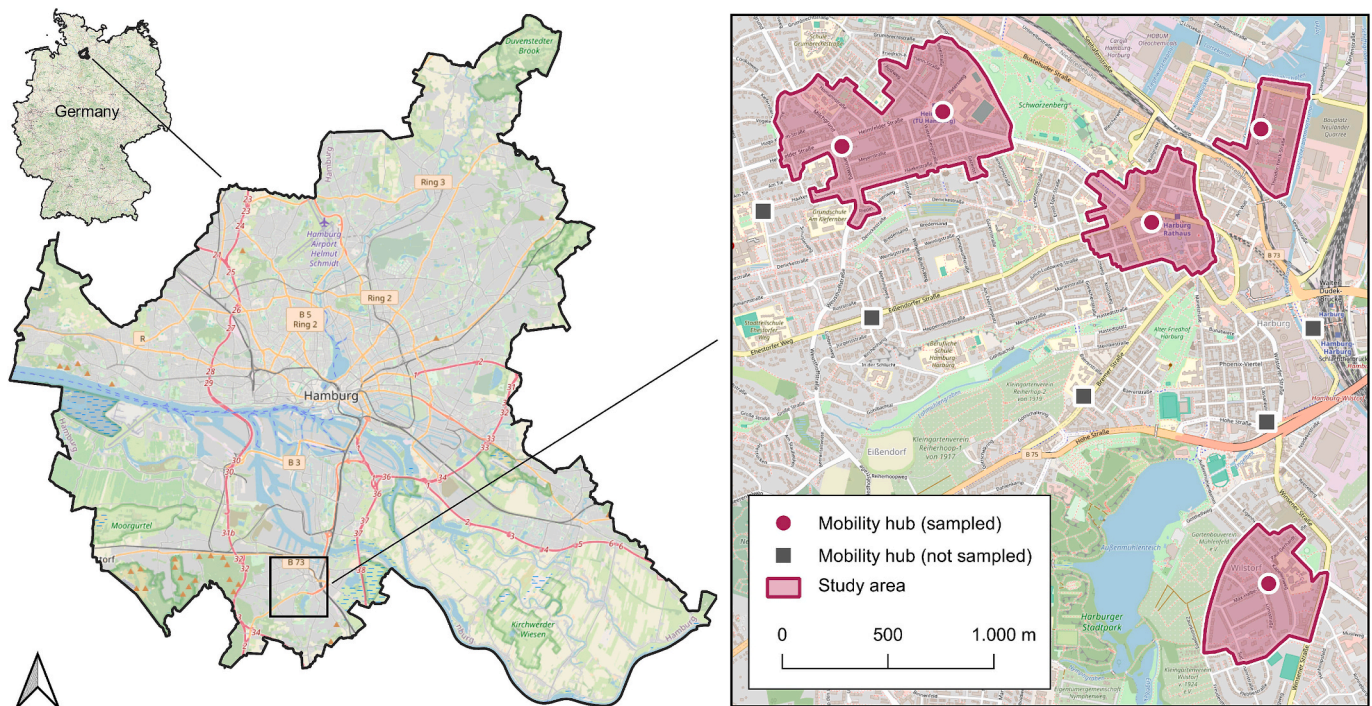


Fig. 2. Study areas and locations of mobility hubs in the southern periphery of Hamburg, Germany.
Source: Authors' own work based on OpenStreetMap and contributors

elaborated upon in this paper.

At the conclusion of the focus groups, participants were asked if they would be willing to be contacted approximately one year later, that is, after the opening of the mobility hubs in their neighborhoods, for follow-up interviews. All 24 participants in the focus groups provided consent, and ultimately, 14 individuals accepted the invitation to participate in an interview when contacted again. The sample of interviewees exhibited diversity with respect to sociodemographic characteristics as well as experiences with carsharing services and mobility hubs (Table 1), thereby allowing for the collection of a range of perspectives. The only exception was that the sample (intentionally) did not include people without a driver's license.

All interviews were conducted in February and March of 2024 at a university located near the designated study areas. The interviews,

which were led by the first author of this paper, lasted between 28 and 52 min and were divided into three major thematic sections. The initial segment of the interview centered on perspectives regarding car ownership, encompassing rationales for owning (or not owning) a car, levels of satisfaction with the status quo, and intentions regarding the acquisition or disposition of a vehicle. The second section of the interview delved into perceptions of carsharing, encompassing both existing usage experiences with carsharing services, particularly in southern Hamburg, and interest in future carsharing use. The third section of the interview concentrated on the mobility hubs, exploring participants' positive or negative opinions of the new hubs and the perceived impacts on their attitudes toward carsharing and car ownership.

The participants in the interviews did not receive financial compensation for their participation; however, they had previously

Table 1
Characteristics of the interviewees and their households.

ID	Personal characteristics					Household characteristics		
	Gender	Age	Main occupation	CS member	MH used	Adults	Minors	Cars owned
1	Male	45	Full-time employed	No, but formerly	No	2	1	2
2	Male	62	Full-time employed	No, never been	No	1	0	0
3	Male	31	Full-time employed	Yes, currently	Yes	2	0	1
4	Male	29	Full-time employed	Yes, currently	Yes	1	0	1
5	Male	40	Full-time employed	Yes, currently	Yes	1	0	1
6	Female	31	Full-time employed	Yes, currently	No	2	0	1
7	Female	40	Full-time employed	No, never been	No	1	0	0
8	Male	32	Part-time employed	Yes, currently	No	2	1	1
9	Male	25	Full-time employed	Yes, currently	No	1	0	1
10	Male	74	Retired	No, never been	No	2	0	1
11	Female	55	Part-time employed	No, never been	No	4	0	1
12	Female	72	Retired	No, but formerly	No	2	0	1
13	Female	53	Full-time employed	No, never been	No	2	0	0
14	Female	27	Full-time employed	Yes, currently	Yes	2	0	1

CS = carsharing; MH = mobility hub.

received 50 euros for their participation in the focus groups. All interviewees provided written informed consent for the conversations to be recorded, transcribed, and used in anonymized form for scholarly publications.

The analysis of the interview transcripts was conducted using qualitative content analysis (Kohlbacher, 2006; Schreier, 2012), combining both deductive (i.e., theory-driven) and inductive (i.e., data-driven) coding approaches. Accordingly, the primary categories of the coding frame were derived chiefly from the interview guide, while the codes

within these categories were developed principally based on the material itself. The coding frame was constructed by the first author in consultation with the co-authors of this paper. An excerpt from the final coding frame, including only the categories and codes relevant to this paper, is provided in Fig. 3. Key insights derived from the interviews are presented in Section 4. The presentation of certain findings is accompanied by quotations, with the interviewee IDs listed in Table 1 serving to identify the respective interviewees. We have translated these quotes from German into English, thereby smoothing out the language and

Categories	Subcategories (Codes)	Interviewees (IDs)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Private car ownership	Zero-car household														
	Car-owning household														
Private car use	Occasional car use (< weekly)														
	Regular car use (≥ weekly)														
Considerations about acquiring or disposing of a car	No change expected in the foreseeable future														
	Reducing or forgoing car ownership is being considered														
Knowledge about carsharing	Has not looked into carsharing in more detail														
	Has already looked into carsharing in more detail														
	Used to be a carsharing member														
	Is currently a carsharing member														
Interest in becoming a carsharing member	Not interested in becoming a carsharing member														
	Interested in becoming a carsharing member														
Frequency of carsharing use	No carsharing use														
	Rare carsharing use (< monthly)														
	Active carsharing use (≥ monthly)														
Problems with or barriers to carsharing use	Carsharing use is too expensive														
	Rent cannot be paused during longer activities														
	Insufficient or unreliable availability of vehicles														
	Insufficient variety of available vehicle types or sizes														
	Insufficient size of carsharing service areas														
Knowledge about the mobility hub	Mobility hub known														
	Mobility hub used														
Effects of the mobility hub on attitudes toward carsharing	No change of attitude toward carsharing														
	Carsharing membership has become more attractive														
	Carsharing use has become more convenient														
Positive aspects of the mobility hub	More reliable, more convenient carsharing access														
	Easier parking of carsharing vehicles														
	Led to the expansion of carsharing service areas														
	Forgoing car ownership has become more attractive														
Problems with the mobility hub	Frequently occupied parking spaces, parking offenders														
	Lack of available vehicles at the mobility hub														
	Mobility hub does not offer any advantages														

Fig. 3. Data matrix showing which codes were applied to which interview transcripts. Filled cells in the columns of the interviewees show that the respective code was applied at least once to the interview transcript. Carsharing members can be identified by the green cells, while non-carsharing members can be identified by the red cells. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

rendering the statements easier to understand without altering their meaning.

3.3. Quantitative approach

In addition to conducting interviews, we administered a survey to residents in close proximity to the newly established mobility hubs. Commencing in November 2023, approximately 5,750 postcards were disseminated to all households within the designated study areas, inviting participation in the survey. The invitation was addressed to a

randomly selected adult member of each household. These postcards contained a concise overview of the survey's context, accompanied by a QR code and a short web address directing interested individuals to an online questionnaire. In order to mitigate the potential for sampling bias, the invitation described the survey as a means of measuring general mobility behavior, while refraining from emphasizing carsharing or mobility hubs as specific topics of the survey. To prevent individuals or households from participating in the survey multiple times, each postcard contained a unique access code that was required to be entered prior to starting the survey. Access to the survey was available until

Table 2

Characteristics of the survey sample, separated into carsharing members and non-carsharing members with a driver's license. Statistical significance of between-group differences was assessed using the Chi-squared test.

Variable	Categories	Carsharing members		Non-carsharing members with a driver's license		p-value
		n	%	n	%	
Gender	Female	53	39.0	90	51.7	0.034
	Male	83	61.0	84	48.3	
Age	18–29	40	29.4	32	18.4	<0.001
	30–44	65	47.8	38	21.8	
	45–64	28	20.6	59	33.9	
	65+	3	2.2	45	25.9	
Household type	Single person	49	36.0	72	41.4	0.016
	Two adults, no minor	59	43.4	69	39.7	
	Two adults, with minor(s)	24	17.6	16	9.2	
	Other	4	2.9	17	9.8	
Educational attainment	Lower secondary education or below	17	12.5	30	17.2	0.498
	Upper secondary education	29	21.3	37	21.3	
	Higher education	90	66.2	107	61.5	
Main occupation	Student/in education	21	15.4	14	8.0	<0.001
	Part-time employed	23	16.9	21	12.1	
	Full-time employed	78	57.4	89	51.1	
	Retired	5	3.7	43	24.7	
	Other	9	6.6	7	4.0	
Socioeconomic status*	Very low	4	2.9	3	1.7	0.135
	Low	8	5.9	17	9.8	
	Medium	39	28.7	56	32.2	
	High	40	29.4	61	35.1	
	Very high	45	33.1	37	21.3	
Car ownership	No car	47	34.6	48	27.6	0.278
	One car	75	55.1	100	57.5	
	Two or more cars	14	10.3	26	14.9	
Private car use	No private car use	51	37.5	61	35.1	0.453
	Less frequently than monthly	13	9.6	13	7.5	
	On 1–3 days per month	14	10.3	11	6.3	
	On 1–3 days per week	36	26.5	50	28.7	
	Daily or almost daily	22	16.2	39	22.4	
Carsharing use	No carsharing use	49	36.0	174	100.0	–
	Less frequently than monthly	61	44.9	0	0.0	
	On 1–3 days per month	21	15.4	0	0.0	
	On 1–3 days per week	3	2.2	0	0.0	
	Daily or almost daily	2	1.5	0	0.0	
Mobility hub known	Yes	96	70.6	98	56.3	0.014
	No	40	29.4	76	43.7	
Mobility hub used	Yes	30	22.1	0	0.0	–
	No	106	77.9	174	100.0	

* The socioeconomic status was determined based on the household's net monthly income and the number of adults, adolescents, and children in the household, following the reference classification for households in Germany by [Nobis and Köhler \(2018\)](#).

February 2024.

The questionnaire sought to collect data on a variety of subjects, including the respondents' car ownership, their typical use of various transportation modes, their attitudes toward and experiences with car-sharing services and mobility hubs in their neighborhoods, as well as the sociodemographic characteristics of the respondents and their households. The survey was designed to require no more than 15 min to be completed.

A total of 393 individuals participated in the survey. To enhance the quality of the sample, all questionnaires from incomplete survey sessions were excluded (30 cases). Among the remaining questionnaires, ten cases were removed in which the survey was completed in less than half the median completion time. This procedure followed the recommendations set forth by Leiner (2019). Furthermore, five cases were excluded in which more than ten percent of the questions were skipped, and four cases were excluded due to inconsistent or suspicious answers. This resulted in a clean sample of 344 participants, corresponding to a response rate of 6 %.

In order to further refine the sample in accordance with the research objectives, 34 respondents without a driver's license were excluded from the study, as these individuals lacked a crucial prerequisite for using carsharing. The final sample for this study comprised 310 individuals in possession of a driver's license, of whom 136 (44 %) were enrolled in at least one carsharing service and 174 (56 %) were not. Among the carsharing members, 30 individuals reported having used the mobility hub in their neighborhood to rent or park carsharing vehicles. The characteristics of the sample, which has been divided into two subsamples (i.e., carsharing members and non-carsharing members in possession of a driver's license), are detailed in Table 2.

All analyses of the survey data were conducted using R 4.4 (R Core Team, 2024). The proportion of missing responses in the cleaned sample was minimal, ranging from 0 % to 3 %, depending on the question. The missing data were subsequently estimated using multiple imputation with the MICE package in R (van Buuren and Groothuis-Oudshoorn, 2011). For null hypothesis significance testing, we considered p-values of less than 0.05 to indicate statistical significance.

4. Key findings from the interviews

The presentation of key findings from the interviews is divided into three subsections. Section 4.1 provides a characterization of the interviewees based on sociodemographic and mobility-related variables to provide a contextual foundation for the subsequent findings. The content of the remaining two subsections is closely aligned with the two research questions of this study. Section 4.2 focuses on findings from the interviews with non-carsharing members in order to investigate the influence of mobility hubs on the interest in future carsharing use. Section 4.3 examines the influence of mobility hubs on the impact of carsharing by presenting findings from interviews with carsharing members.

4.1. Characteristics of the interviewees

The ages of the 14 interviewees (Table 1) ranged from 25 to 74 years ($M = 44$; $SD = 17$). Eight of the interviewees (57 %) were men. Ten individuals (71 %) were employed full-time, while two (14 %) worked part-time and another two were retired. Two individuals had children, and the rest predominantly came from single-person (five individuals, 36 %) or childless two-person (six individuals, 43 %) households.

Car ownership was widespread, with only three individuals (21 %) living in car-free households. However, with one exception, all car owners had only one car in their household. Eight of the eleven car owners used their car at least once a week.

Interviewees with and without carsharing membership made up half of the sample each. Among the seven carsharing members, actual carsharing use varied considerably: two individuals practically never used carsharing, three used it rarely, and two used it at least monthly. All

carsharing members were enrolled exclusively in free-floating carsharing services.

As expected, all interviewees were aware of the mobility hub in their neighborhoods. Four of the seven carsharing members (or four of the five active carsharing users) had already used the mobility hub themselves at the time of the interview.

4.2. Findings from the interviews with non-carsharing members

Four of the seven interviewees who did not possess a carsharing membership stated that they had become more involved with carsharing options since the mobility hubs opened. This included, for example, researching available carsharing providers and their terms of use. Five non-carsharing members, including two former members, expressed a genuine interest in using carsharing in the future. This interest manifested itself in different ways, ranging from a concrete intention to use carsharing in the coming weeks to a general openness to enroll in carsharing in the medium to long term (e.g., when a decision has to be made on whether to replace the currently owned car).

The interviews suggested a direct link between the introduction of mobility hubs and an increased interest in using carsharing. All five individuals expressing interest in carsharing indicated that the mobility hub had rendered carsharing more appealing to them. In particular, the increased visibility of carsharing vehicles in prominent locations and the ease of access to these locations appeared to motivate interviewees to contemplate their own utilization of carsharing, as evidenced by the following quote from an interviewee without a private vehicle:

"I definitely noticed it [the mobility hub] in a positive way. I mean, I often walk by it and think, 'Oh, look, there's a car from [carsharing company] and right next to it, another one from [another carsharing company].' So they're just really present there. I've noticed them so often now that I'd say, 'Okay, if I ever need a car, then I've got one pretty much right here, practically right outside my door.'" (ID7)

One newly enrolled carsharing member even reported that he had only joined carsharing shortly before the interview, in part because of the now more visible carsharing options:

"I have to admit, I was standing in front of it [the mobility hub] three days ago, and there was this small electric car from [carsharing company] parked there. And I thought, 'Oh, I really ought to try that out.' I've always wanted to do something like that. So I signed up with [carsharing company] right away, scanned my driver's license and everything. So theoretically, I could have done it right then, but I didn't. But I've decided to take a spin around the block in the next few days, just to give it a try." (ID9)

Two non-carsharing members explained that the mobility hub facilitated their consideration of replacing their private car with carsharing, although the mobility hub appeared to be a supporting factor for such considerations rather than the actual cause. In one instance, the emphasis was exclusively on relinquishing a secondary private vehicle; in the other, the interviewee's household contemplated fully renouncing car ownership:

"Well, I often pass by that mobility hub coming from the bus stop. [...] And we've talked at home quite a few times about getting rid of our car completely, especially now that there's this hub nearby, for the few times that we actually need a car... I mean, we haven't quite made the decision yet on that front, but we've been seriously considering it lately." (ID12)

However, interviewees also mentioned problems at the mobility hubs. Two non-carsharing members noted repeated misuse of the dedicated carsharing parking spaces by private vehicles. In at least one case, this misuse reduced, but did not eliminate, interest in using carsharing:

“This mobility hub can be a bit tricky, because it happens quite often that the carsharing spots are just parked in by others. And then the question is, when you come with your carsharing ride and want to drop it off, what do you do then? [...] Well, I guess I’d have to figure it out when it happens. But it’s a problem that, from what I’ve seen, occurs fairly often.” (ID2)

Beyond this, none of the interviewees reported observing any issues with the mobility hubs that would have posed a significant deterrent to joining carsharing. However, the inherent limitations of the carsharing offer in the urban periphery, which remained largely unaffected by the presence of mobility hubs, emerged to be significantly more substantial impediments. Five of the seven non-carsharing members identified the high cost of carsharing as a salient issue. One critique directed at carsharing companies concerned the design of their pricing models, which are predominantly tailored for shorter urban trips. Consequently, the cost of relatively long trips from the periphery to the city center was often considered excessive. Four non-carsharing members further noted that even trips from the urban periphery to the suburbs of Hamburg—despite the modest distances—would result in unreasonably high costs, as the rental cannot be stopped during longer activities there. For two non-carsharing members who did not intend to join carsharing, the high costs were the primary reason why their attitude toward carsharing had not improved despite the introduction of mobility hubs. One of them offered the following description:

“What am I supposed to get out of this [the mobility hub]? I mean, I’d really like to use carsharing to go to [a place in the suburbs of Hamburg], for example. But the catch is, if I head out there, I basically have to rent the car the whole time and bring it back with me. [...] But then I’ve probably rented the car for like five hours, even though it’s only about ten kilometers, which seems way too expensive to me.” (ID11)

Conversely, the potential barriers to carsharing use that mobility hubs are designed to mitigate were indeed seldom cited as concerns by non-carsharing members in the interviews. Insufficient availability of carsharing vehicles or an inadequate selection of vehicle types was mentioned by only one interviewee each as an obstacle to joining carsharing. However, it is important to acknowledge that certain quality criteria of carsharing services, such as vehicle availability or the selection of available vehicle types, may not be fully assessed by individuals without experience using carsharing services. In this regard, the perspectives of carsharing users, which will be examined in the subsequent section of this paper, carry greater significance.

4.3. Findings from the interviews with carsharing members

Of the seven interviewees who possessed carsharing memberships, four had already gained experience with the mobility hub in their neighborhood by using it to rent or park carsharing vehicles. Three of the four mobility hub users reported that the hubs had made carsharing significantly more convenient for them. In particular, the enhanced reliability of vehicle and parking space availability was identified as a significant improvement by four and three mobility hub users, respectively. The following quotations illustrate this:

“I see carsharing more positively now. Because the mobility hub provides a certain level of reliability. When I see a carsharing vehicle parked on the street, I can’t trust it’s still gonna be there an hour later. That’s not exactly the case at the mobility hub either, but there’s a concentration of cars there. In my experience, my chances of finding a car there are high. Every time I needed one, it was there, so it’s definitely a win.” (ID4)

“I think it’s awesome. I mean, I heard the mobility hub was going to open, so I kept an eye out. [...] Since then, carsharing has been way less stressful, because I already know where to look for a parking spot. I also always know which route to take so that I arrive on the side of the street where the hub is. I basically park there whenever possible, unless it’s full, then I have to start searching and I have the same problem as with my own

car. But the chances of finding a parking spot [for carsharing vehicles] are higher now that the mobility hub is here.” (ID14)

Moreover, two carsharing members lauded the expansion of the service area for free-floating carsharing that occurred in tandem with the implementation of the mobility hubs. This expansion can be attributed to the fact that some of the mobility hubs under study were constructed in locations that were not served by all of the free-floating carsharing companies operating in Hamburg at the time. Consequently, certain companies have extended their service areas to encompass these peripheral locations.

The interviewees reported no changes in car ownership subsequent to the opening of the mobility hubs. However, the enhanced reliability and convenience of carsharing has prompted two members to express their serious consideration of giving up car ownership in the foreseeable future. In response to inquiries regarding the impact of the mobility hub on his perspective regarding car ownership, one interviewee who owned a relatively aged vehicle provided the following response:

“It gets you thinking when you walk by the mobility hub and see the cars. And it will really make me think when I have to decide whether I need a new car or not. I’d probably try to get by without owning a car first and rely on carsharing. Of course, I’ll have to see if it’s cost-effective in the long run, especially for weekend trips and stuff. But I definitely see it more as a real option now.” (ID9)

Nevertheless, carsharing members also encountered challenges related to the mobility hubs. Three carsharing members—two of whom were users of the mobility hubs—expressed criticism regarding the repeated misuse of the dedicated parking spaces by unauthorized parkers. While the interviewees found this inconvenient, it did not appear to change their generally positive opinion of the mobility hubs.

In contrast, three of the carsharing members interviewed did not perceive any positive impact of the mobility hubs on their attitude toward carsharing. In one particular instance, this was explicitly attributed to the fact that several attempts to use the mobility hub failed due to a lack of available vehicles. Two other carsharing members, one of whom had previously used a mobility hub, expressed a lack of perception of benefit from the hubs. They asserted that access to carsharing vehicles and parking spaces was sufficient without the presence of mobility hubs. These insights were conveyed in statements such as the following:

“I mean, sure, I see the mobility hub every time I do my grocery shopping, so it’s pretty visible to me, but it doesn’t really mean much. Because the few times I wanted to use carsharing there, there wasn’t a car I could take.” (ID6)

“I honestly don’t see the big advantage in it. I used to find a carsharing vehicle nearby even before the hub existed. The cars from [carsharing company] aren’t tied to stations anyway. I’ve always found one so far. Sure, if someone parks a car at the hub and it’s close, I’ll go there. But I’m just as happy if the car’s a block away on the corner, it makes no difference to me.” (ID8)

5. Key findings from the survey

In addition to conducting interviews with residents living near the mobility hubs, we administered a survey to investigate whether certain findings from the interviews could be confirmed using a broader sample of the population in the vicinity of the hubs. As with the findings from the interviews, the survey results are presented in three subsections. In [Section 5.1](#), the survey sample is characterized, divided into two subsamples: carsharing members and non-carsharing members who possessed a driver’s license. [Section 5.2](#) explores whether the mobility hubs can be associated with more favorable attitudes toward carsharing and heightened interest in using carsharing, based on data from surveyed non-carsharing members. [Section 5.3](#) leverages data from

carsharing members, with a focus on those who have utilized a mobility hub, to investigate the potential impact of these hubs on the willingness of carsharing users to forgo car ownership.

5.1. Characteristics of the survey sample

An overview of the characteristics of the surveyed carsharing members and non-carsharing members with a driver’s license is provided in Table 2. As anticipated, respondents lacking carsharing membership exhibited more heterogeneous sociodemographic characteristics, manifesting, for instance, in a more equitable distribution between younger and older age groups and a more balanced gender ratio. Conversely, carsharing members tended to be predominantly male, young or middle-aged (i.e., under 45 years old), students, and full-time employees. The data also suggested higher levels of educational attainment and socio-economic status among carsharing members, although these differences did not reach statistical significance. Overall, the data confirmed the typical sociodemographic profile of carsharing members known from previous studies (Amirmazmiazfar and Diana, 2022; Nansubuga and Kowalkowski, 2021).

Contrary to predictions, however, carsharing members did not exhibit significantly lower levels of car ownership or car use, although the differences between the groups did tend in that direction. This observation may be partially attributed to the fact that the overwhelming majority of carsharing members, specifically 93 %, were exclusively registered with free-floating carsharing. Previous research has indicated that this particular type of carsharing exerts a considerably weaker influence on car ownership compared to round-trip schemes

(Becker et al., 2017; Chicco et al., 2022; Namazu and Dowlatabadi, 2018). In addition, a considerable proportion of carsharing members (36 %) were inactive, meaning that they did not actually use carsharing services. The high proportion of inactive members likely resulted from the fact that all carsharing providers in the study area offered memberships without monthly base fees.

As would be expected, a substantially higher percentage of carsharing members (71 %) were already aware of the existence of the mobility hub in their neighborhood compared to non-carsharing members (56 %). However, only 22 % of carsharing members reported personal experience of using the mobility hub.

5.2. Findings from the survey of non-carsharing members

The implementation of the mobility hubs on the southern periphery of Hamburg occurred without the support of major advertising campaigns. Consequently, only slightly more than half of the non-carsharing members surveyed were aware of the existence of mobility hubs in their respective neighborhoods. This enabled the division of non-carsharing members into two similar-sized subgroups: those who were aware (98 individuals) and those who were not aware (76 individuals) of the mobility hub’s presence in their neighborhood. This approach was taken to identify potential differences in attitudes toward carsharing that might be attributable to the mobility hubs.

Attitudes of non-carsharing members were measured using the eight psychometric items shown in Fig. 4, which respondents were asked to answer on a five-point Likert scale (from 1 = “strongly disagree” to 5 = “strongly agree”). Some of these items targeted attitudes that we

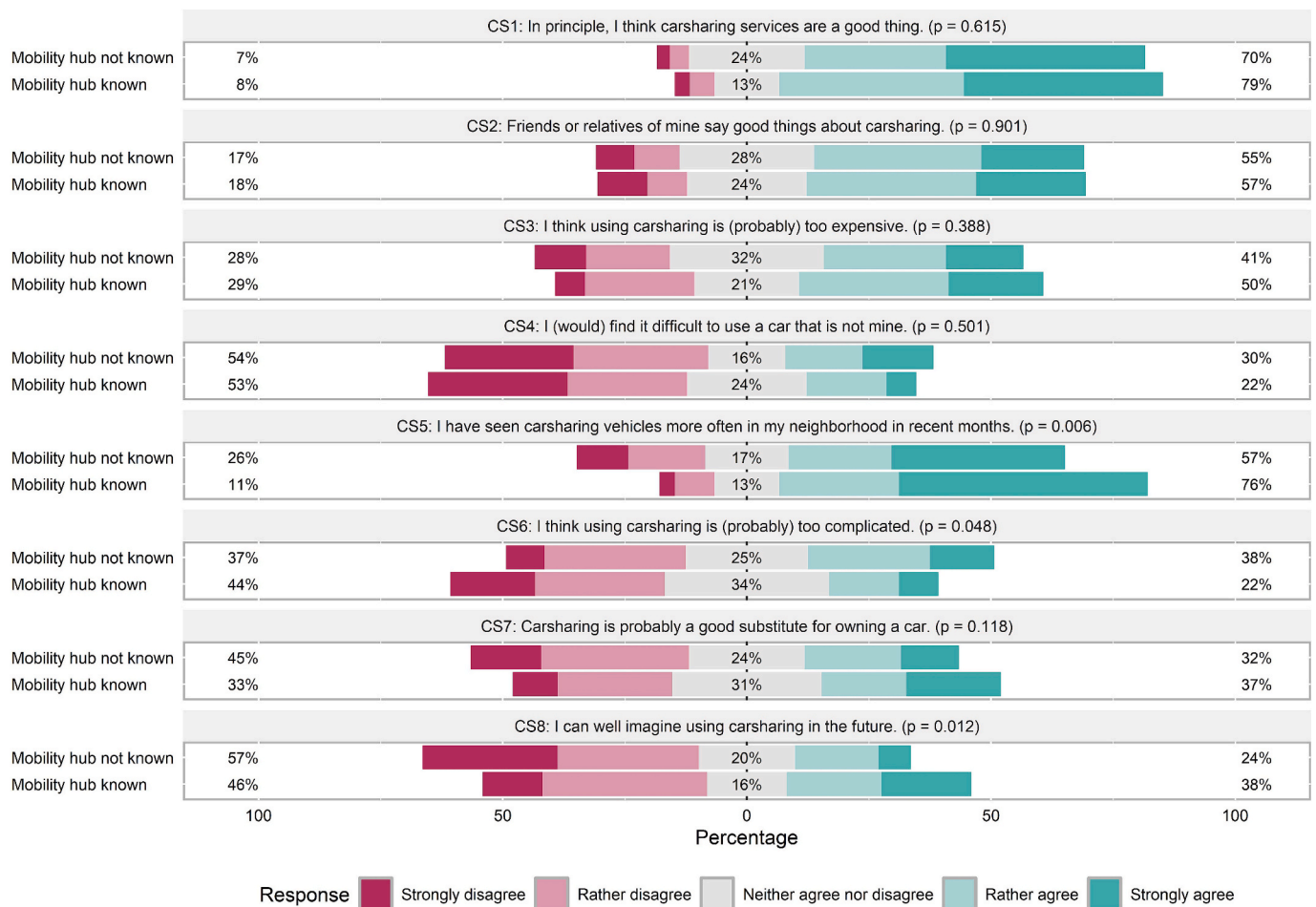


Fig. 4. Attitudes of non-carsharing members toward carsharing in relation to whether they knew of the existence of the mobility hub in their neighborhood. Statistical significance of between-group differences was assessed using the Mann-Whitney U test.

expected to change through exposure to the mobility hub, such as the opinion that carsharing could be a good substitute for car ownership, or the interest in using carsharing in the future. Conversely, the remaining items addressed attitudes that were unlikely to be influenced by the mobility hub, such as the general willingness to use a car that does not belong to the individual, or the perception that carsharing is too expensive. This approach allowed us to test whether the non-carsharing members with and without knowledge of the mobility hub in their neighborhood differed fundamentally or only in aspects that could be significantly influenced by the mobility hubs. The items were randomly rotated during the survey to mix both types of items so that respondents would not notice any pattern.

The results (Fig. 4) indicate that non-carsharing members with and without knowledge of the mobility hub did not differ significantly in attitudes that were presumably not influenced by the hubs. For instance, responses to statements that carsharing is principally a good thing (Item CS1: $p = 0.615$) and that friends or relatives speak favorably about carsharing (Item CS2: $p = 0.901$) showed no significant between-group differences. Furthermore, the perception of whether carsharing is too expensive (Item CS3: $p = 0.388$) and how challenging it would be to use a car not owned by oneself (Item CS4: $p = 0.501$) were found to be relatively similar between the two subgroups.

Conversely, we identified statistically significant between-group differences in the items anticipated to be influenced by exposure to the mobility hubs. Individuals who were aware of the mobility hub in their neighborhood were more likely to agree that they had noticed carsharing vehicles in their neighborhood more frequently over the past few months (Item CS5: $p = 0.006$). On the other hand, the perception that using carsharing is or might be (too) complicated was significantly less prevalent among individuals aware of the mobility hub (Item CS6: $p = 0.048$). Moreover, the data suggested that awareness of the mobility hub was associated with a more favorable opinion of carsharing as a potential alternative to private vehicles; however, the difference between the subgroups did not attain statistical significance in this instance (Item CS7: $p = 0.118$). Conversely, a significant difference emerged concerning whether non-carsharing members could envision using carsharing in the future, with respondents who were acquainted with the mobility hub exhibiting a considerably higher likelihood of concurrence (Item CS8: $p = 0.012$).

5.3. Findings from the survey of carsharing members

In order to identify potential effects of the mobility hubs on the willingness to reduce or forgo car ownership, we examined trends in the number of cars owned by surveyed carsharing members in relation to whether they had used the mobility hub. To this end, respondents were asked to report how many cars their household owned *at the time* of the survey, how many cars their household owned twelve months *prior* to the survey, and how many cars they expected their household to own twelve months *after* the survey. Based on these data, we investigated whether there were significant changes in car ownership among three groups of carsharing members: *all* carsharing members without mobility hub use (106 individuals), all *active* carsharing users *without* mobility hub use (57 individuals), and carsharing members *with* mobility hub use (“mobility hub users”; 30 individuals). The term “active carsharing users” was defined as individuals who reported utilizing carsharing at least on an occasional basis. The necessity of considering active carsharing users without mobility hub use as a discrete group stems from the fact that the mobility hub users were also exclusively active carsharing users. Consequently, a comparison of mobility hub users with *all* carsharing members—including inactive ones—who had not used the mobility hub is limited in its validity, although we included it in the analysis to better contextualize the results.

In the questionnaire, questions regarding past, present, and future car ownership were administered prior to inquiries concerning the use of carsharing and mobility hubs. This was intended to minimize the risk

that respondents would recognize the connection between these questions and deliberately overstate their willingness to forgo car ownership due to social desirability.

The data collected on respondents’ car ownership (Fig. 5) revealed that carsharing members who had not used the mobility hub showed only a slight, statistically not significant decrease in car ownership over the observed period of about two years. This finding persisted when examining all carsharing members without mobility hub use (Plot A) and when focusing exclusively on active carsharing users among them (Plot B). This outcome was not necessarily to be expected, as there is ample evidence in the extant literature that carsharing reduces private car ownership (e.g., Giesel and Nobis, 2016; Le Vine and Polak, 2019; Jochem et al., 2020; Ye et al., 2021). However, it is imperative to acknowledge that the period under scrutiny was relatively brief and did not encompass any prospective changes in car ownership that may be planned further in the future. Research has shown that decisions to reduce car ownership are often executed with a temporal lag. For instance, individuals may opt against actively disposing of an old private car, preferring instead to not replace it with a new one at the conclusion of its service life (Jin et al., 2022). Moreover, an overwhelming majority of surveyed carsharing members were registered exclusively with free-floating carsharing, which, according to extant research, exerts a weaker influence on car ownership than round-trip carsharing (Becker et al., 2017; Chicco et al., 2022; Namazu and Dowlatabadi, 2018).

Among mobility hub users (Fig. 5, Plot C), no statistically significant change in car ownership was observed in the first half of the period under review, that is, in the year prior to the survey. However, mobility hub users appeared to be more willing to reduce or give up their car ownership in the twelve months following the survey. Consequently, when examining the *complete* period from twelve months prior to twelve months after the survey, the data for mobility hub users suggested a statistically significant reduction in the number of private cars.

In order to gain a more profound understanding of the usage and impact of the mobility hubs, we asked their users to respond to a set of eight psychometric items (Fig. 6). These items focused on attitudes toward, as well as positive and negative experiences with, the mobility hubs. In a manner consistent with the attitudinal questions posed to non-carsharing members (Section 5.2), the responses to these items were measured on a five-point Likert scale.

According to the responses, 17 % of mobility hub users indicated that the hub in their neighborhood contributed to their decision to enroll in carsharing (Item MH1). This proportion is relatively low; however, it should be noted that the mobility hubs were less than a year old at the time of the survey. Consequently, the majority of users were likely already enrolled in carsharing services prior to the implementation of the hubs. The remaining items indicated predominantly favorable opinions of the mobility hubs. A mere 17 % of users reported that they did not perceive any tangible benefits from the mobility hub in their neighborhood (Item MH2). In contrast, 63 % of users concurred that the mobility hub facilitated ease of use for carsharing (Item MH3). However, only 27 % indicated that the mobility hub led to an increase in the frequency of carsharing use (Item MH4). The perception of the user-friendliness of mobility hubs was less favorable, with one third of users expressing dissatisfaction with the availability of carsharing vehicles and parking spaces at their hub, respectively (Items MH5 and MH6). Furthermore, 70 % of users reported feeling inconvenienced by parking violations at the mobility hub (Item MH7), and 57 % reported that they could not use their mobility hub as often as they would have liked due to a lack of carsharing vehicles or parking spaces (Item MH8).

In addition to examining users’ perceptions of the benefits and challenges associated with mobility hubs, we also investigated the factors that *prevented* carsharing members from utilizing these hubs. To this end, all 66 surveyed carsharing members who were aware of the existence of the mobility hub in their neighborhood but had not used it were asked to provide reasons. The responses were then categorized, as shown in Fig. 7.

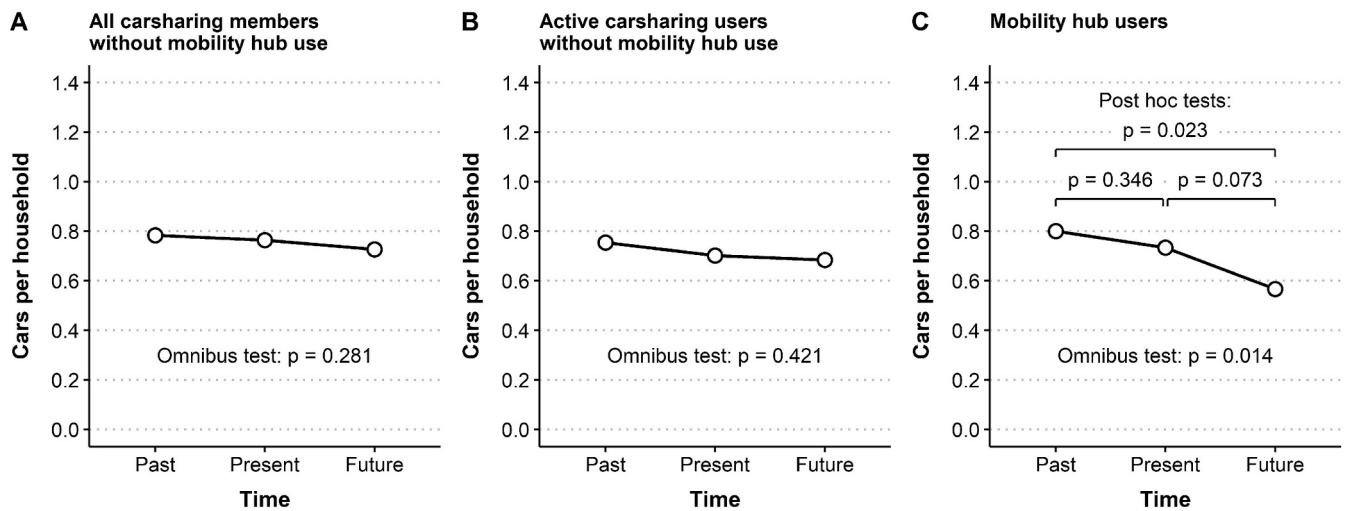


Fig. 5. Trends in car ownership by carsharing members and their subgroups. The figure shows the mean number of cars owned by households twelve months prior to the survey (“Past”), at the time of the survey (“Present”), and the anticipated car ownership twelve months following the survey (“Future”). Statistical significance of changes over time was assessed using the Friedman test as an omnibus test and, where appropriate, Wilcoxon signed-rank tests for the post-hoc analysis.

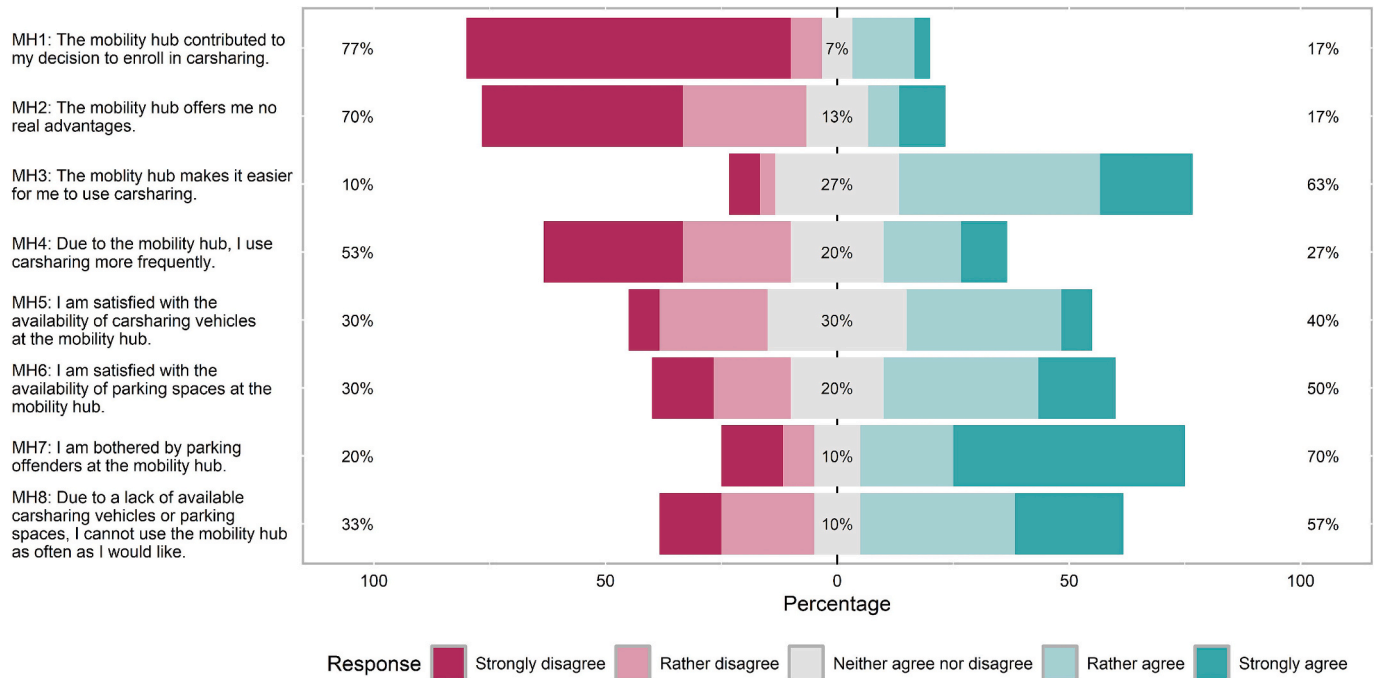


Fig. 6. Attitudes of mobility hub users toward the mobility hub in their neighborhood.

Given the relatively high proportion of inactive carsharing members, it was not surprising that 48 % of non-users indicated that they had simply not been in a situation to use the mobility hub due to infrequent or no carsharing use. Furthermore, 35 % of non-users indicated that they did not perceive a necessity for the mobility hub, suggesting that they typically found carsharing vehicles and parking spaces in other locations. However, a considerable proportion of the responses fell into categories suggesting involuntary non-use of the mobility hubs. For instance, 23 % of non-users indicated that they did not utilize the mobility hub in their neighborhood due to their unfamiliarity with the terms of use. This often led to uncertainty regarding whether it was permissible to park a vehicle from their preferred carsharing provider at the mobility hub. Moreover, 23 % of non-users reported that no vehicles from their preferred carsharing provider were available at the mobility hub, and 12 % could not find a free parking space at the hub.

6. Discussion and conclusion

6.1. Integration of qualitative and quantitative findings

The objective of this study was to examine the impact of mobility hubs, equipped with designated carsharing parking spaces, on the adoption and impact of carsharing in the urban periphery of a major city. Specifically, we investigated whether non-carsharing members develop an interest in using carsharing by being exposed to a mobility hub in their neighborhood, and whether carsharing users become more inclined to reduce or forgo car ownership as a result of using such a hub. To this end, we conducted interviews with residents living near newly implemented mobility hubs in the southern periphery of Hamburg, Germany, as well as a survey of the population around these hubs, including both individuals with and without experience using

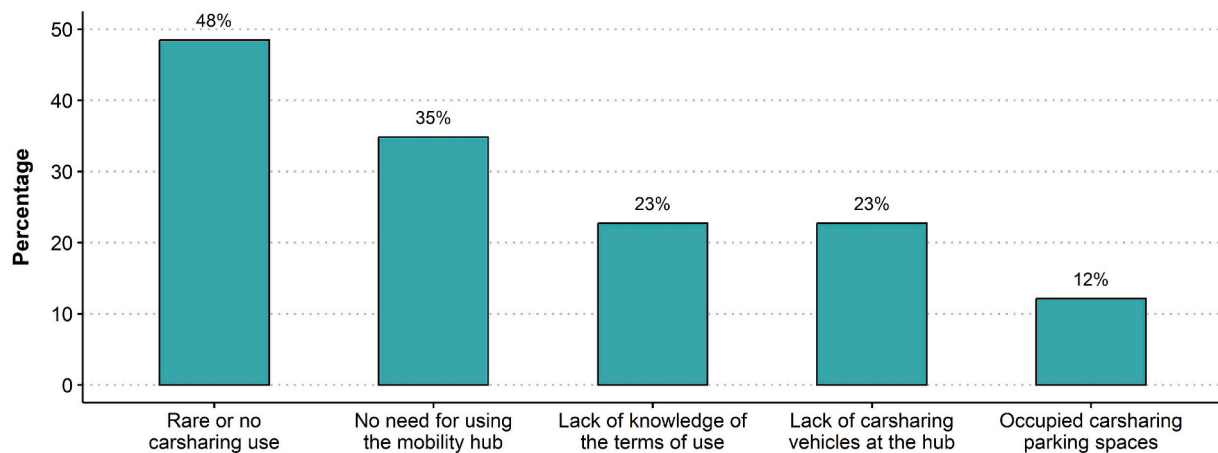


Fig. 7. Reasons given by carsharing members for not using mobility hubs. The figure is based on responses from all carsharing members who were aware of the existence of the mobility hub in their neighborhood but had not used it. The sum of the percentages exceeds one hundred, as respondents were permitted to provide multiple reasons.

carsharing services and mobility hubs. In accordance with the convergent mixed-methods approach employed in this study (Creswell and Clark, 2017), the qualitative and quantitative findings were presented separately in the preceding sections and are discussed jointly in this section to facilitate a more comprehensive understanding of the effects of peripheral mobility hubs.

The findings from the interviews and survey consistently demonstrated that the mobility hubs under study resulted in heightened interest in carsharing among non-carsharing members. The interviews revealed that the rise in interest can be attributed to enhanced accessibility of carsharing vehicles and parking spaces, as well as the increased visibility of carsharing options through mobility hubs. This observation was corroborated by the survey results, which indicated that non-carsharing members who were aware of the mobility hub in their neighborhood exhibited heightened awareness of local carsharing options, expressed less apprehension regarding the presumed difficulty of using carsharing, and demonstrated a greater propensity to consider future use of carsharing services. Moreover, the results of the interviews and survey showed that a proportion of carsharing members had signed up for carsharing specifically because of the mobility hub.

The enhanced accessibility to carsharing vehicles and exclusive parking spaces through mobility hubs also exerted a favorable influence on carsharing users. The survey results indicated that two-thirds of carsharing users who had utilized their neighborhood mobility hub felt that carsharing had become more convenient. Additionally, one in three mobility hub users reported an increase in carsharing use attributable to the mobility hub. Consequently, mobility hubs appeared to strengthen the perception of carsharing as a viable alternative to car ownership, as the utilization of mobility hubs among carsharing users was linked to a higher willingness to reduce or forgo car ownership in the near future. However, between the establishment of the mobility hubs and the period during which our data were collected, there was no indication that the hubs had exerted a substantial influence on car ownership. It is plausible that this absence of impact could be attributed to the relatively brief period of approximately one year since the hubs' inauguration.

However, our research also identified deficiencies in the mobility hubs and their interaction with carsharing. The issue of occupied parking spaces, particularly by unauthorized parkers at mobility hubs, was a recurring theme in both interviews and the survey, although this was generally perceived as an inconvenience rather than a serious disruption. Conversely, significant barriers to the utilization of carsharing and mobility hubs emerged from inherent issues with carsharing services in urban periphery, over which mobility hubs exert minimal to no control. Specifically, excessive costs associated with carsharing—particularly for trips across city limits—were identified as a major

impediment to its use in both the interviews and the survey. Another salient issue pertained to the perception of insufficient carsharing vehicle availability, not only at the mobility hubs but also in the broader periphery of Hamburg. In this respect, our findings on barriers to mobility hub use closely follow those of Bösehans et al. (2023), who, using the Dutch city of Amsterdam as their study area, also showed that the cost of renting vehicles, uncertainties about vehicle availability, and the lack of options for ending the rental at the desired location can deter potential mobility hub users from actually using them.

In addition to the costs of using carsharing and the limitations in terms of available vehicles and parking spaces, the impact of the mobility hubs was also constrained by the lack of awareness among the local population regarding these facilities. Approximately one year following the establishment of the hubs, nearly half of the non-carsharing members and almost a third of the carsharing members surveyed were unaware of the presence of a mobility hub in their neighborhood, despite the fact that the survey was conducted exclusively among individuals residing within a 400-meter distance of a mobility hub. Furthermore, among carsharing members who were aware of the mobility hubs but had not used them, a lack of familiarity with the terms and conditions for using the hubs was among the most commonly cited reasons for non-use.

In summary, the findings of this study demonstrate that the implementation of mobility hubs in the periphery of a major city can indeed promote the adoption of carsharing. With respect to the potential enhancement of carsharing's impact on car ownership, the results of our study were not as unambiguous. During the period between the opening of the hubs and the time of data collection, we were unable to identify any substantial differences in car ownership between carsharing members who used the mobility hubs and those who did not. However, when planned or anticipated future changes in car ownership were considered, the results indicated a greater willingness among mobility hub users to reduce or forgo car ownership, suggesting a delayed effect of the mobility hubs.

Earlier research has shown that mobility hubs have the capacity to amplify the acceptance and usage of carsharing (Miramontes et al., 2017; Liao et al., 2024), as well as the impact of carsharing on car ownership and travel behavior (Czarnetzki and Siek, 2023). Moreover, the pivotal role of convenient access to carsharing vehicles and parking spaces in fostering the uptake and impact of carsharing is well-documented in prior studies (e.g., Cantelmo et al., 2022; Czarnetzki, 2023; Dowling and Kent, 2015; Ko et al., 2019; Namazu et al., 2018; Wang et al., 2020). However, the extant literature has predominantly centered on urban areas that are conducive to the proliferation of carsharing. To the best of our knowledge, our study is the first to focus

explicitly on mobility hubs in the urban periphery, where the successful establishment of carsharing faces considerably greater challenges. These challenges were also evident in our data, for example in the relatively widespread car ownership and (private) car use among the interviewees and survey participants, as well as in the fact that eight out of ten surveyed carsharing members did not use carsharing services even once a month. Nevertheless, our findings indicate that the implementation of mobility hubs, equipped with carsharing vehicles and designated car-sharing parking spaces, constitutes an effective approach to promoting carsharing as an alternative to car ownership, even under relatively unfavorable conditions in the urban periphery.

Concurrently, our findings also indicate that to amplify the beneficial impacts of mobility hubs in the urban periphery, their implementation must be complemented by supplementary measures. This includes measures targeted at improving the use and usability of the mobility hubs themselves, such as complementary advertising and information campaigns, as well as strict penalties for parking violations at the hubs. However, the efficacy of mobility hubs in the urban periphery remains constrained unless they are accompanied by comprehensive measures that aim to enhance carsharing services in these areas on a broader scale. This refers to increasing carsharing fleet sizes in the urban periphery, expanding the service areas of carsharing providers beyond city limits, and implementing pricing models that allow for cost-effective utilization of carsharing services in both urban and suburban areas.

6.2. Limitations

Although the consistency between our interview and survey results builds confidence in the reliability of our findings, some methodological limitations of our study must be considered. With regard to the interviews, it is probable that individuals with favorable attitudes toward carsharing and mobility hubs were overrepresented among the interviewees. This can be attributed to the fact that all interviewees had previously engaged in focus groups prior to the establishment of the mobility hubs. Consequently, they were already known to possess at least a rudimentary interest in these hubs. While this approach had the advantage of ensuring that all interviewees were familiar with the research topic, it is likely that this also limited the diversity of perspectives captured. Furthermore, it is important to consider that the sample size of our qualitative research approach totaled only 14 interviewees.

Regarding the survey, it should be noted that the observed associations between variables such as awareness of mobility hubs and interest in carsharing, or use of mobility hubs and willingness to reduce or give up car ownership do not permit reliable conclusions about causal relationships due to the use of cross-sectional data. Our interpretation of the survey results is that awareness and use of mobility hubs lead to more positive perceptions of carsharing, as this effect was also evident in the interviews as well as in previous research on mobility hubs in central Hamburg (Czarnetzki and Siek, 2023). However, reverse causality cannot be ruled out. For example, it is conceivable that non-carsharing members with a pre-existing interest in carsharing were more likely to become aware of the new mobility hubs, or that particularly active (and satisfied) carsharing users were more likely to use mobility hubs. However, it is unlikely that this has led to fundamentally biased results.

Finally, it must be kept in mind that, as a case study, our work prioritized in-depth understanding of a single phenomenon over producing broadly generalizable results. Consequently, the findings of this study may not be directly transferable to cities and regions with significantly different characteristics, for example in terms of car ownership and car use. Recent reviews of the literature on mobility hubs indicate considerable variation in the effects of these hubs depending on their geographical context (Arnold et al., 2023a; Nikitas et al., 2025; Xu et al., 2025). Moreover, the fact that almost all carsharing members among the interviewees and survey participants in our study used free-floating carsharing exclusively may further limit the generalizability of

our findings. Research has shown that free-floating carsharing differs significantly from other carsharing schemes in terms of user demographics, usage patterns, and effects (Becker et al., 2017; Chicco et al., 2022; Lempert et al., 2019; Namazu and Dowlatabadi, 2018; Ramos et al., 2023). Therefore, this case study is to be regarded as part of a larger body of research necessary to gain a complete understanding of mobility hubs and their effects.

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

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

CRediT authorship contribution statement

Felix Czarnetzki: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maximilian Philip Freude:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Conceptualization. **Carsten Gertz:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The survey data that has been used will be made available upon reasonable request. The interview transcripts are confidential.

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