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The effects of exclusive on-street carsharing parking on carsharing perception and car ownership: A structural equation modeling approach

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Abstract: Carsharing is considered an effective tool for reducing car ownership, especially in high-density urban areas. Dedicated on-street carsharing parking spaces (CPS) are a promising but under-researched approach to increase the attractiveness and impact of carsharing. Since 2017, Hamburg, Germany, has focused on providing small clusters of such carsharing parking spaces in inner-city residential neighborhoods. This paper is based on survey data of users of these parking spaces. A structural equation model is applied to examine the effects of exclusive carsharing parking spaces on the perception of carsharing as well as on car ownership of carsharing users. The results confirm that the provision of exclusive and conveniently accessible carsharing parking spaces promotes the perception of carsharing as a viable substitute for private cars, which ultimately leads to lower actual car ownership. However, perceived usability constraints of these facilities, such as long access distances or parking violations, lead to significant losses in their effectiveness.

Keywords: Carsharing, car ownership, parking policy, public space, street space allocation, urban mobility

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1 Introduction and background

Several studies in recent years have shown that carsharing leads to a reduction of private car ownership among users (e.g., Becker et al., 2017; Giesel & Nobis, 2016; Jochem et al., 2020; Ko et al., 2019; Le Vine & Polak, 2019; Namazu & Dowlatabadi, 2018). However, the acceptance and thus the overall impact of carsharing is strongly determined by its accessibility and convenience. In order to promote and facilitate carsharing as an alternative to private car use and ownership, research has emphasized the importance of dedicated and easily accessible carsharing parking spaces (Abbasi et al., 2021; Chen et al., 2018; Costain et al., 2012; De Luca & Di Pace, 2015; Paundra et al., 2017; Wang et al., 2020), especially in high-density urban areas where there is fierce competition for parking supply (Dowling & Kent, 2015). Based on stated preference methods, previous studies have highlighted the role of carsharing parking convenience (Paundra et al., 2017), as well as access time to dedicated carsharing parking spaces (De Luca & Di Pace, 2015) and vacant carsharing vehicles (Diana & Ceccato, 2022) as key determinants of carsharing attractiveness. Cantelmo et al. (2022) even showed that dedicated carshar-

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ing parking spaces are the most important direct incentive to promote carsharing, according to current and potential carsharing users. The importance of easily accessible carsharing parking is also indicated by the research of Ampudia-Renuncio et al. (2018), Herrmann et al. (2014), and Rotaris et al. (2019), who consistently found that the willingness of current and potential users to rent a car decreases sharply when the access distance to the nearest available carsharing vehicle exceeds 500 meters.

However, especially in highly urbanized areas of large cities, finding suitable locations for dedicated carsharing parking can be challenging due to limited space. As a result, a number of researchers have proposed the reallocation of regular on-street parking spaces to carsharing-only parking (e.g., De Lorimier & El-Geneidy, 2013; Dowling & Kent, 2015; Glotz-Richter, 2016: Liao et al. 2020). Yet, despite repeated advocacy for carsharing-supportive parking policies, the literature lacks empirical evidence from the study of actually implemented on-street carsharing parking spaces and their users that would allow more robust conclusions to be drawn about the impact of such facilities.

Figure 1. Dedicated carsharing parking spaces at a mobility hub in the inner-city district of Eimsbüttel, Hamburg (Image source: Author)

This paper aims to investigate the effects of exclusive on-street carsharing parking spaces (CPS) on carsharing perception and car ownership, using a transport policy intervention in Hamburg, Germany's second largest city, as a case study. Since 2017, neighborhood mobility hubs have been installed in various high-density residential areas in Hamburg's city center. In general, mobility hubs are defined as recognizably designed places that concentrate different mobility options, often focusing on shared mobility services and their integration with conventional public transport (Coenegrachts et al., 2021; Rongen et al., 2022). Neighborhood mobility hubs are smaller types of mobility hubs that are characterized by a lower number and complexity of services, resulting in their catchment area being mostly limited to individual neighborhoods (Rongen et al., 2022; Weustenenk & Mingardo, 2023). In Hamburg, a total of 75 such neighborhood mobility hubs—branded as "hvv switch stations"—were established by the end of 2022. At each of these mobility hubs, there are typically three to four dedicated CPS where vehicles from specific authorized free-floating or station-based carsharing providers can be rented and parked (Figure 1). The sites for the CPS were created by converting ordinary public on-street parking spaces. Offering CPS at the mobility hubs is intended to increase the reliability and convenience of carsharing for residents of these neighborhoods, so that carsharing can have a stronger impact on private car ownership.

From 2019 to 2020, a scientific evaluation of the perception and use of Hamburg's neighborhood mobility hubs as well as their influence on the mobility behavior of local residents was carried out. The evaluation was commissioned by Hamburger Hochbahn AG, the city's largest public transport operator. Part of the data collected for the evaluation has been used in this paper. Previously published results of the evaluation have shown that regular use of neighborhood mobility hubs supports a modal shift towards sustainable mobility among carsharing users, while infrequent use of mobility hubs does not lead to such an effect (Czarnetzki & Siek, 2022). So far, however, factors such as repeated misuse of the CPS at mobility hubs by private cars or a lack of available carsharing vehicles at these locations have partially limited their usability.

Against this background, I conducted the present study with two objectives. The first objective was to focus more closely on the CPS in order to estimate their specific effects on the perception of carsharing as a viable alternative to private cars, as well as on the actual car ownership of carsharing users. The second objective was to investigate to what extent these effects depend on the perceived usability of the CPS.

My first hypothesis (H1) was that higher levels of CPS usability (as measured by user-reported satisfaction with the accessibility and availability of carsharing vehicles and parking spaces at these locations) would positively influence CPS efficacy (as measured by reported changes in carsharing and private car use due to the CPS). In addition, I expected that positive perceptions of both the usability (H2) and efficacy (H3) of the CPS would increase the perception of carsharing as an alternative to car ownership, and that a more positive perception of carsharing would ultimately reduce the odds of private car ownership in the households of carsharing users (H4). As a result, I expected that the usability (H5) and efficacy (H6) of the CPS would indirectly reduce car ownership, mediated by the positive perception of carsharing. Because these hypotheses were interrelated, I used a structural equation model (SEM) to test their validity.

2 Methods and data

2.1 Data collection and preparation

From October to December 2019, I conducted a survey in the vicinity of 16 randomly selected neighborhood mobility hubs with CPS (Figure 2). Only hubs that had been in operation for more than six months at the time of the survey were sampled, to ensure that carsharing users in the vicinity of the mobility hubs had sufficient time to become familiar with the new offerings. The average age of the sampled hubs was 13 months at the time of data collection. I delineated the study areas around each of the 16 hubs using a walking distance of 400 meters. I then mailed postcards to all addressable households within these areas, inviting one randomly selected adult from each household to participate in a web survey. In total, postcards were mailed to approximately 17,350 households, of which 2,261 individuals accessed the questionnaire. During the data checking and cleaning process, I excluded any questionnaires that were not completed, were completed exceptionally quickly, or contained questionable information (Figure 3). This left 2,003 questionnaires, resulting in an adjusted response rate of 11.5%.

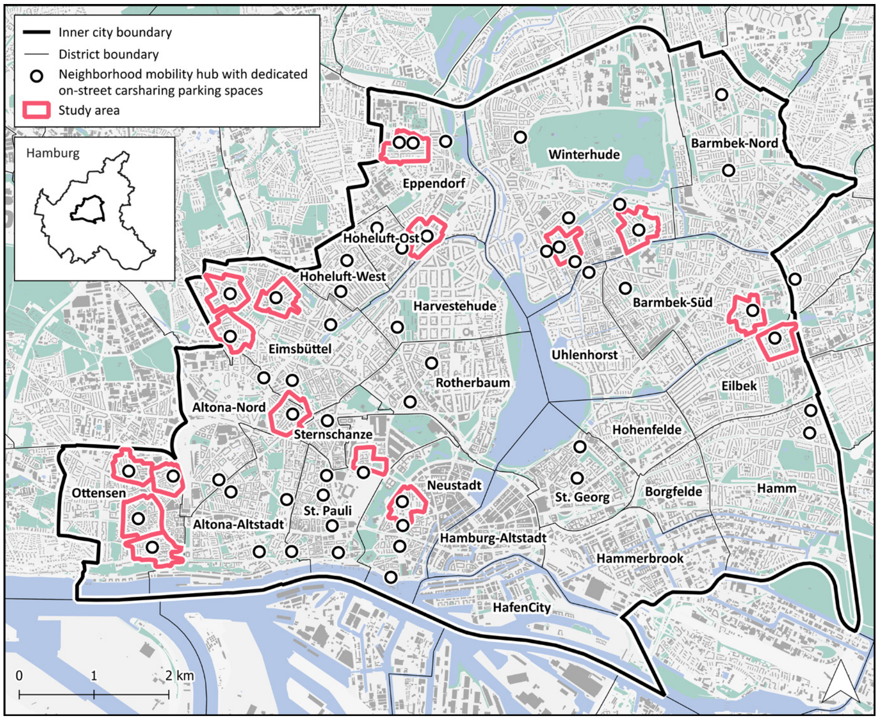

Figure 2. Map of the inner city of Hamburg, showing the locations of the neighborhood mobility hubs (as of November 2019, i.e., at the time of data collection) and the study areas; delineation of the inner-city area is based on Matthes & Gertz (2014) (Map source: Own work based on OpenStreetMap and contributors)

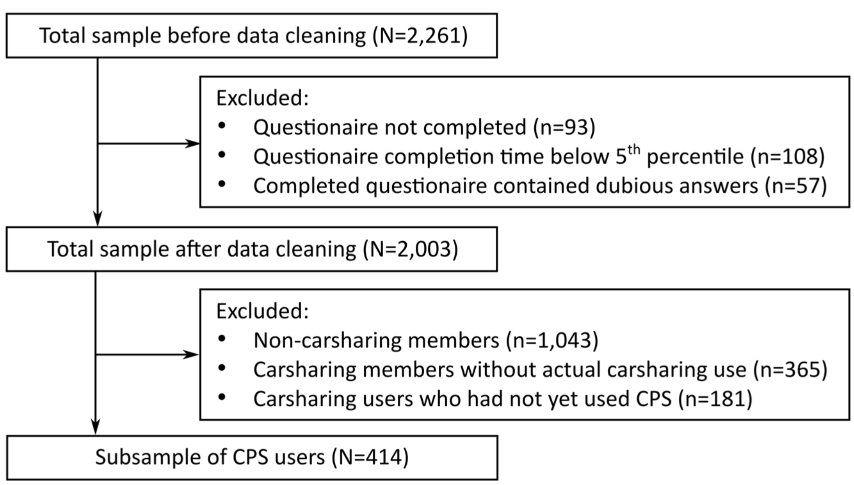

Figure 3. Flowchart showing the data cleaning process and the determination of the subsample consisting of users of dedicated carsharing parking spaces (CPS)

The use of carsharing and the CPS was not a prerequisite for participation in the survey. For this paper, I therefore reduced the total sample to the relevant cases by excluding all non-carsharing members, all carsharing members without actual carsharing use, and all carsharing users who had not yet used the CPS in their neighborhood (Figure 3). The resulting subsample consisted of 414 respondents who reported at least occasional carsharing use and had already gained experience using the CPS, that is, had already started and/or ended carsharing trips in these locations.

2.2 Characteristics and representativeness of the sample

Table 1 presents descriptive statistics for the sample of CPS users and compares them with data from the German National Household Travel Survey (NHTS) "Mobilität in Deutschland 2017" (Follmer et al., 2020; Nobis & Kuhnimhof, 2018,) to assess the representativeness of the sample. The NHTS data for Hamburg were provided by the city's transport authority. To increase comparability with the surveyed CPS users, I trimmed the NHTS data to individuals who reported using carsharing at least occasionally and who lived in the inner-city area of Hamburg shown in Figure 2.

The CPS users included in the sample were predominantly male, young or middle-aged. Most of them lived in one- or two-person households. A clear majority of the sampled CPS users were employed. They also tended to have high levels of education and socioeconomic status. These characteristics are consistent with findings from previous studies on the typical demographic and socioeconomic characteristics of carsharing users (Becker et al., 2017; Ceccato & Diana, 2021; Giesel & Nobis, 2016; Kopp et al., 2015; Prieto et al., 2017; Wittwer & Hubrich, 2018). I found no statistically significant differences between the sample and the NHTS data on these characteristics (i.e., $p>0.05$), and even for the comparisons with relatively low p-values, the effect sizes remained negligible (i.e., Cramér's $V<0.1$) according to standard thresholds (Cohen, 1992). Therefore, I considered the sample to be reasonably representative of the population of carsharing users in the inner city of Hamburg.

Table 1. Characteristics of the sample used for this study and comparison with data from the German National Household Travel Survey (NHTS) "Mobilität in Deutschland 2017" (Note that for some variables no NHTS data were available, CS = carsharing; CPS = dedicated carsharing parking spaces)

	Sample		NHTS		χ^2 test of homogeneity	
	n	%	n	%	*p*	Cramér's V
Gender						
Male	233	56.3	269	62.3	0.089	0.06
Female	181	43.7	163	37.7		
Age						
18–29 years	73	17.6	73	16.9	0.080	0.09
30–44 years	180	43.5	224	51.9		
45–64 years	147	35.5	122	28.2		
≥65 years	14	3.4	13	3.0		
Household size						
1 person	133	32.1	128	29.6	0.312	0.05
2 persons	174	42.0	204	47.2		
≥3 persons	107	25.8	100	23.1		
Presence of child(ren)						
No child in the household	306	73.9	340	78.7	0.119	0.05
≥1 child(ren) in the household	108	26.1	92	21.3		
Educational attainment						
Below academic degree	96	23.2	115	26.6	0.283	0.04
Academic degree	318	76.8	317	73.4		
Employment						
Unemployed/not in workforce	48	11.6	53	12.3	0.844	0.01
Part-time or full-time employed	366	88.4	379	87.7		

Socioeconomic status						
Low or very low	37	8.9	23	5.3	0.102	0.09
Medium	111	26.8	126	29.2		
High	158	38.2	184	42.6		
Very high	108	26.1	99	22.9		
Cars owned by the household						
No car	216	52.2	198	45.8	0.002	0.12
1 car	174	42.0	179	41.4		
≥2 cars	24	5.8	55	12.7		
Frequency of private car use						
Never or almost never	134	32.4	100	23.1	0.008	0.13
Less than once a month	67	16.2	75	17.4		
1 to 3 days per month	65	15.7	78	18.1		
1 to 3 days per week	93	22.5	91	21.1		
Daily or almost daily	55	13.3	88	20.4		
Number of CS services used						
1 service	134	32.4	208	48.1	<0.001	0.16
≥2 services	280	67.6	224	51.9		
Types of CS services used						
Free-floating carsharing only	288	69.6	.	.	.	.
Round-trip carsharing only	34	8.2	.	.		
Both types	92	22.2	.	.		
Frequency of CS use						
Less than once a month	80	19.3	197	45.6	<0.001	0.30
1 to 3 days per month	218	52.7	178	41.2		
1 to 3 days per week	107	25.8	55	12.7		
Daily or almost daily	9	2.2	2	0.5		
Distance from home to CPS						
≤100 meters	89	21.5	.	.	.	.
101–200 meters	114	27.5	.	.		
201–300 meters	149	36.0	.	.		
301–400 meters	62	15.0	.	.		
Frequency of CPS use						
Less than once a month	237	57.2	.	.	.	.
1 to 3 days per month	127	30.7	.	.		
1 to 3 days per week	46	11.1	.	.		
Daily or almost daily	4	1.0	.	.		
Sample size (N)	414		432			

It was also consistent with expectations that car ownership and car use were low among CPS users; 52% of them lived in a car-free household and 49% reported that they never or rarely (i.e., less than once a month) used a private car. Although the sample was already adjusted for inactive carsharing members, a significant proportion of respondents (19%) used carsharing less frequently than monthly, which is in line with previous findings on typical carsharing usage patterns (Ko et al., 2019; Namazu & Dowlatabadi, 2018; Nobis & Kuhnimhof, 2018). Since, as expected, not every carsharing trip started or ended at the CPS, the frequency of use of these parking spaces was even lower. Of respondents, 43% used the CPS in their neighborhood on a regular basis (i.e., at least monthly). Not surprisingly, CPS were used more frequently by those who lived closer to these facilities. For example, among those who could reach the nearest CPS within 100 meters of their home, 65% reported using the CPS at least monthly. In contrast, among respondents who lived within 300 to 400 meters of the CPS, only 23% reported using these CPS at least monthly.

When comparing the sample of CPS users with the NHTS data in terms of car ownership and use of private cars and carsharing services, statistically significant differences were found (Table 1). However, it should be taken into account that the aim of the CPS was to influence precisely these variables. In fact, all differences pointed in the expected direction (i.e., less car ownership and less frequent use of private cars, but more frequent use of carsharing by CPS users). In addition, the differences between CPS users and NHTS data on carsharing use were probably amplified by the sampling procedure, as the probability of having used the CPS was likely related to the frequency of carsharing use in general.

The sample of CPS users was also characterized by a particularly high proportion of respondents who used free-floating one-way carsharing (FFCS), either exclusively (70%) or in combination with station-based round-trip carsharing (SBCS; 22%). Although NHTS data were not available for comparison, I assumed this distribution to be plausible, as the carsharing market in Germany's largest cities is dominated by a few large FFCS operators, which account for the vast majority of carsharing members (Bundesverband CarSharing, 2023).

2.3 Psychometric measures

In addition to questions about socio-demographics, car ownership, and travel behavior, the web survey included several psychometric questions about perceptions of carsharing and the CPS (Table 2, Figure 4). A five-point Likert scale was provided for responses. Only the outer points of the scale were explicitly named ("strongly disagree" and "strongly agree," respectively). I developed the psychometric questions based on 15 qualitative, semi-structured interviews that I had conducted in 2019 in preparation for the survey. The interviewees were carsharing users who lived near neighborhood mobility hubs and had experience using the CPS.

Table 2. List of the psychometric questions used as indicators. CPS = dedicated carsharing parking spaces (Note that this abbreviation was not used in the survey. The questionnaire was in German; the questions were translated for this paper by the author)

Indicator	Psychometric question
X_1	I am satisfied with the proximity of the CPS to my home.
X_2	I am satisfied with the availability of vacant carsharing vehicles in the CPS of my neighborhood.
X_3	I am satisfied with the availability of vacant CPS in my neighborhood.
Y_1	The CPS in my neighborhood make it easier for me to use carsharing.
Y_2	Because of the CPS in my neighborhood, I use carsharing more often.
Y_3	Because of the CPS in my neighborhood, I use a private car less often.
Y_4	In my neighborhood, the distance to the nearest available carsharing vehicle is often too far for me.
Y_5	In my neighborhood, it is difficult to find a parking space for a carsharing vehicle.
Y_6	Carsharing allows me to organize my everyday life more flexibly and freely.
Y_7	Without carsharing, important destinations would be difficult for me to reach.
Y_8	Carsharing is an adequate substitute for owning a car.

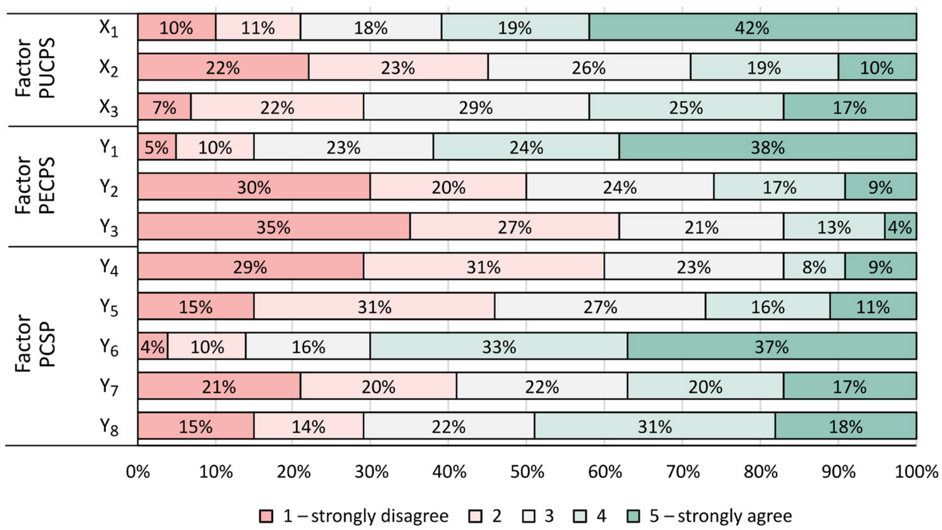

Figure 4. Distributions of the responses to the psychometric questions; PUCPS = Perceived usability of carsharing parking spaces; PECPS = Perceived efficacy of carsharing parking spaces; PCSP = Positive carsharing perception

A number of respondents did not answer all of the psychometric questions. The proportion of missing responses ranged from 1.3% for indicator Y_6 to 5.1% for indicator Y3. I replaced missing values with estimated values, relying on multivariate imputation by chained equations using the R package MICE (Van Buuren & Groothuis-Oudshoorn, 2011) in R 4.1.

2.4 Model specification

Within the measurement model of the SEM (Figure 4), I used the psychometric questions as indicators to construct three hypothesized factors. The factor "Perceived usability of carsharing parking spaces" (PUCPS) was measured by respondents' satisfaction with the accessibility of the CPS in their neighborhood (X_1) and the availability of vacant carsharing vehicles (X_2) and parking spaces (X_3) at these facilities. To estimate the factor "Perceived efficacy of carsharing parking spaces" (PECSP), respondents were asked whether the CPS in their neighborhood had facilitated their use of carsharing (Y_1), and whether they had used carsharing more often (Y_2) and private cars less often (Y_3) because of the CPS. To model the third factor, "Positive carsharing perception" (PCSP), I first used respondents' general satisfaction with the accessibility of carsharing vehicles (Y_4) and with the usual time spent looking for parking at the end of their carsharing trips (Y_5) in their respective neighborhoods. Thus, these two indicators addressed typical barriers to carsharing use that the CPS were designed to mitigate. In addition, respondents were asked to what extent carsharing had increased their flexibility in everyday life (Y_6) and made it easier for them to reach important places (Y_7). Finally, this factor was also measured by whether respondents saw carsharing as a viable substitute for car ownership (Y_8).

I then specified the structural model of the SEM (Figure 5) based on my aforementioned hypotheses. Car ownership in respondents' households was used as the outcome variable. Initially, I measured the number of cars owned by households as a count variable. However, since car ownership among CPS users only ranged from zero to two cars, and two-car households accounted for only 6% of the sample, I dichotomized this variable and distinguished only whether respondents lived in a car-owning household

(1=yes; 0=no). I expected that the odds of living in a car-owning household would be directly influenced by positive carsharing perception. In turn, positive carsharing perception was modeled to be directly driven by the perceived usability and efficacy of the CPS. However, I did not consider a direct effect of the CPS on car ownership because I assumed that the usability and efficacy of the CPS would only indirectly influence car ownership, with positive carsharing perception acting as a mediating variable. Furthermore, the perceived efficacy of the CPS was expected to be directly influenced by the perceived usability of the CPS.

Finally, to improve model fit, I allowed for correlation between residual variances of certain indicators where it was substantively plausible. For example, residual covariance in general satisfaction with the accessibility of carsharing vehicles (Y_4) and the availability of carsharing parking (Y_5) in respondents' neighborhoods may have been caused by variables not included in the model. Such variables could be, for example, characteristics of the neighborhood, of the carsharing services used, or of the respondents themselves. Unlike all other model parameters, residual correlations were included only as a post hoc modification to further improve model fit after estimating an initial model without such correlations.

SEM estimations were performed with the help of the R package lavaan (Rosseel, 2012). For additional analyses of the reliability and validity of the hypothesized factors, I used the R packages psych (Revelle, 2022) and semTools (Jorgensen et al., 2022). The assumption of multivariate normal distribution was violated by some of the indicators, and the structural model included a binary outcome. Therefore, I relied on a robust variant of the diagonally weighted least squares (DWLS) estimator based on a mean-and-variance corrected test statistic (WLSMV estimator), which has been shown to perform well under these circumstances (Li, 2016; Rhemtulla et al., 2012). Relationships with p-values less than 0.05 were considered statistically significant.

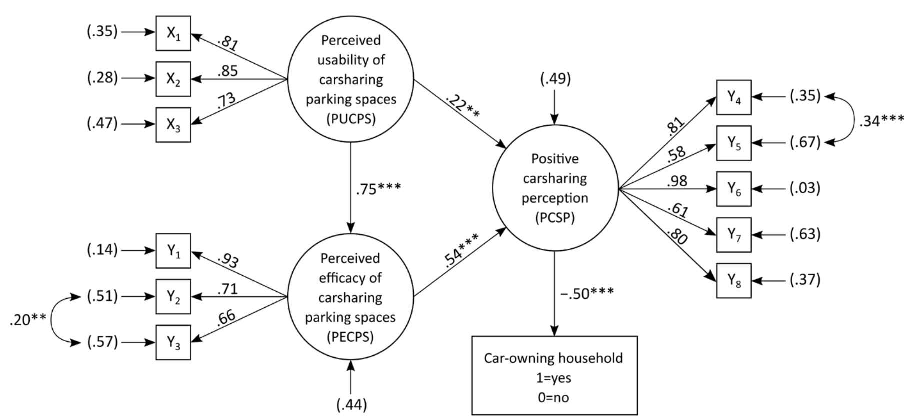

Figure 5. The final structural equation model. Indicators of the exogenous factor are denoted by X_i, while indicators of the endogenous/mediating factors are denoted by Y_i. Indicators Y_4 and Y_5 (inverted items) were recoded prior to model estimation; all path coefficients are standardized; the values in parentheses indicate the unexplained variance (residuals) of the observed and latent variables; statistical significance is indicated as follows: $^{**}p<0.01$; $^{***}p<0.001$; all factor loadings were statistically significant at $p<0.001$

3 Results

3.1 Reliability and validity assessment

The results of the measurement model within the SEM showed that the hypothesized factors were well represented by their indicators. Most of the factor loadings clearly exceeded values of 0.6 (Figure 5). To assess the reliability of the factors, I first calculated Cronbach's Alpha (α) and interpreted it according to the recommendations of Nunnally et al. (1978). In addition, Composite Reliability (CR) was used as a second reliability coefficient, which is particularly recommended in the context of structural equation modeling (Peterson & Kim, 2013; Raykov, 2001). Convergent validity was assessed using average variance extracted (AVE: Fornell & Larcker, 1981), while discriminant validity was assessed using the heterotrait-monotrait ratio of correlations (HTMT: Henseler et al., 2015; Voorhees et al., 2016).

The reliability coefficients of the factors PUCSP (α=0.84, CR=0.84), PECSP (α=0.83, CR=0.83), and PCSP (α=0.87, CR=0.88) consistently indicated good reliability. Convergent validity was considered achieved as the average variance extracted by each factor (PUCSP: 0.64; PECSP: 0.62; PCSP: 0.58) was well above the minimum recommended threshold of 0.5 (Fornell & Larcker, 1981). To achieve discriminant validity, heterotrait-monotrait ratios of correlations between all pairs of factors should be less than 0.85 (Henseler et al., 2015), which was the case for this model (range of HTMT ratios: 0.67–0.74).

3.2 Path analysis and hypothesis testing

Measured against the usual thresholds recommended in the literature (Hu & Bentler, 1999), the fit indices of the final SEM (as shown in Figure 5) indicated a close fit to the data ($\chi^2[49]=236.04$, $p<0.001$; CFI=0.98; RMSEA=0.045 [90% CI: 0.039–0.051]; SRMR=0.05). It should be noted, however, that conventional cutoffs for acceptable model fit were developed for models involving maximum likelihood (ML) estimation and continuous data, whereas the present model involved diagonally weighted least squares (DWLS) estimation and categorical data. Previous research (Xia & Yang, 2018) has shown that the DWLS estimator leads to smaller values of the root mean square error of approximation (RMSEA) and larger values of the comparative fit index (CFI), thereby increasing the likelihood of accepting a misfit model. However, the standardized root mean square residual (SRMR) is robust to the estimation method (Shi & Maydeu-Olivares, 2020). Given the aforementioned values of the goodness-of-fit indices and their distances from the usual cutoffs, the model adequately represented the data, even though some of the goodness-of-fit statistics may have been affected by the estimation method.

Table 3. Results of the path analysis within the structural equation model; the values shown are standardized coefficients, with their respective standard errors in parentheses; PUCPS = Perceived usability of carsharing parking spaces; PECSP = Perceived efficacy of carsharing parking spaces; PCSP = Positive carsharing perception; car-owning household was a binary variable coded as 1=yes and 0=no; statistical significance is indicated as follows: **p<0.01; ***p<0.001

Direct effects			
Path	⟶ PECPS	⟶ PCSP	⟶ Car-owning household
PUCPS ⟶	0.75 (0.09)***	0.22 (0.08)**	·
PECPS ⟶	·	0.54 (0.09)***	·
PCSP ⟶	·	·	–0.50 (0.06)***
Indirect effects			
Path	⟶ PECPS	⟶ PCSP	⟶ Car-owning household
PUCPS ⟶	·	0.41 (0.08)***	–0.31 (0.05)***
PECPS ⟶	·	·	–0.27 (0.05)***
PCSP ⟶	·	·	·
Total effects			
Path	⟶ PECPS	⟶ PCSP	⟶ Car-owning household
PUCPS ⟶	0.75 (0.09)***	0.62 (0.08)***	–0.31 (0.05)***
PECPS ⟶	·	0.54 (0.09)***	–0.27 (0.05)***
PCSP ⟶	·	·	–0.50 (0.06)***

The results of the structural model within the SEM confirmed the underlying hypotheses (Table 3). As expected, perceived CPS usability had a strong direct effect on perceived CPS efficacy (H_1: β=0.75, SE=0.09, p<0.001). Both perceived usability (H_2: β=0.22, SE=0.08, p=0.009) and perceived efficacy of the CPS (H_3: β=0.54, SE=0.09, p<0.001) had significant direct effects on positive carsharing perception. In addition, positive carsharing perception was even more indirectly influenced by perceived usability of the CPS (β=0.41, SE=0.08, p<0.001). Positive perception of carsharing, in turn, had a substantial negative effect on the odds of car ownership in CPS user households (H_4: β=–0.50, SE=0.06, p<0.001, B=–0.47, OR=0.63). When all estimated relationships were combined into total effects, perceived efficacy of the CPS was shown to significantly reduce the odds of car ownership (H_6: β=–0.27, SE=0.05, p<0.001, B=–0.25, OR=0.78). Unsurprisingly, given its fundamental role in the model, perceived usability of the CPS was found to have an even stronger total effect on the odds of car ownership (H_5: β=–0.31, SE=0.05, p<0.001, B=–0.28, OR=0.75).

In practical terms, the results mean that if a CPS user's positive perception of carsharing (operationalized as the PCSP factor score) increases by one standard deviation, the odds of that person living in a car-owning household are reduced by approximately 37%. If a CPS user's PUCSP factor score increases by one standard deviation (i.e., the usability of dedicated carsharing parking spaces is perceived as significantly improved), that person's positive carsharing perception increases by 0.62 standard deviations, and the odds of car ownership in that person's household are reduced by approximately 25%.

4 Discussion and conclusion

The model was able to verify that exclusive on-street carsharing parking in high-density, inner-city residential neighborhoods leads to a more positive perception of carsharing among its users. Typical barriers to carsharing use—namely the distances to the next vehicle and the search for parking at the end of a carsharing trip—are significantly reduced by the provision of such dedicated spaces. As a result, carsharing is increasingly seen as an attractive alternative to the private car, which means that more carsharing users are actually willing to forego car ownership. The conversion of public on-street parking spaces into exclusive carsharing parking spaces can therefore be seen as an effective measure to promote the reduction of car ownership by reallocating street space.

However, urban and transportation planners considering the implementation of dedicated on-street carsharing parking need to keep in mind that the user-perceived usability of these spaces is paramount to their success. A key element for their effective implementation is a dense distribution of such spaces within residential neighborhoods. The sample used for this paper was already limited to carsharing users who could reach dedicated carsharing parking spaces within a maximum walking distance of 400 meters from their homes. However, even within these relatively small study areas, a significant proportion of respondents were dissatisfied with the accessibility of carsharing parking, and the frequency of use of the carsharing parking spaces decreased substantially with increasing distance from the respondent's home. The planning of exclusive on-street carsharing parking spaces should therefore be based on the assumption of relatively small catchment areas. In addition, as there is a particular risk of misuse of dedicated carsharing parking spaces by private vehicles in high-density areas characterized by limited parking, it is essential to provide strong deterrents against parking violations. Keeping the parking spaces free of unauthorized cars should also result in local residents finding more carsharing vehicles at these locations, resulting in better vehicle availability, which is another important contributor to the usability and effectiveness of dedicated on-street carsharing parking.

5 Limitations

When interpreting the results, it is important to consider the limitations of this study. A major methodological limitation is that only cross-sectional data could be used and no appropriate control group data were available. Although the structural equation model fitted the data well and the underlying hypotheses were confirmed, the results do not allow causal inferences about predictive associations, nor can they distinguish between unidirectional and reciprocal relationships. Therefore, further research on the effects of dedicated on-street carsharing parking is needed, ideally using longitudinal methods.

A limitation to the generalizability of the findings is the high proportion of free-floating carsharing users in the sample; 92% of respondents used this type of carsharing exclusively or in parallel with station-based carsharing. Previous studies have found that free-floating carsharing has a weaker impact on car ownership than its station-based counterpart (Becker et al., 2017; Chicco et al., 2022; Giesel & Nobis, 2016; Namazu & Dowlatabadi, 2018). This can be explained, in part, by the lower reliability and predictability of access to and parking of vehicles operated by free-floating carsharing services (Glotz-Richter, 2016). Station-based carsharing, on the other hand, is already inherently associated with designated and reliable locations for renting and parking its vehicles. Although station-based carsharing may benefit from increased visibility and accessibility due to dedicated on-street carsharing parking spaces, it is arguably free-floating carsharing that benefits most from these facilities. Therefore, the findings of this study may have limited applicability to cities where station-based carsharing is predominant or even the only type of carsharing available. However, it would be a valuable contribution of future research to investigate whether and to what extent the impact of exclusive on-street carsharing parking actually differs between carsharing types.

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Conflict of interest

The author declares that the research was conducted in the absence of any financial interests or personal relationships that could be construed as a potential conflict of interest.

Data availability

The data that support the findings of this study are not publicly available as they are part of an ongoing dissertation, but are available from the author upon reasonable request.

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