Journal of Cycling and Micromobility Research 2 (2024) 100029

Contents lists available at ScienceDirect

Journal of Cycling and Micromobility Research

journal homepage: www.sciencedirect.com/journal/journal-of-cycling-and-micromobility-research

Shared mobility - Novel insights on mode substitution patterns, trip and user characteristics

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ARTICLE INFO

Keywords:
Active travel
Shared mobility
Electric mobility
Travel behaviour
Mode substitution
Quantitative data analysis

ABSTRACT

With a growing number of shared mobility options, choosing not to own a car may become a new norm in the future. Shared mobility offers users a flexible range of low or zero-emission alternatives, potentially reducing the use of private cars, as well as noise and air pollution. However, to date, there is little evidence of shared mobility acting as an alternative to private car use. Indeed, recent research suggests that shared vehicles not only substitute trips by private car, but also trips by active travel and public transport, thus not resulting in emission savings. Therefore, as part of the eHUBS project focusing on shared electric mobility hubs, the mode substitution patterns of 602 self-reported shared mobility users across Europe were investigated. More specifically, respondents of an online survey were asked to recall their last trip using shared mobility and to report on both their chosen and substituted travel mode in addition to common trip characteristics including trip distance and frequency. Chosen shared modes considered were both conventional or electric alternatives including cars, bicycles, cargobikes, and scooters. Overall, the results suggested that shared vehicles were about as or more likely to substitute public transport, cycling and walking, as private car trips, thus providing a mixed picture with respect to their potential contribution to reducing private car use and associated carbon emissions. Local authorities and policy makers are urged to actively continue to improve active travel facilities and to be proactive in better integration of shared mobility and public transport services.

1. Introduction

Currently, the EU is not on track to achieve zero-carbon transport in line with the Paris agreement (Plötz et al., 2021). Various political-economic factors are either slowing down or preventing the transition to a less car-dependent, or even car-independent society, thus maintaining the status quo (Mattioli et al., 2020). Electric vehicles (EVs) may help to reduce greenhouse gas emissions (GHG) but are associated with other problems, such as increased energy use required to produce the powertrain and batteries (Verma et al., 2022). Moreover, EVs neither solve congestion nor societal health problems (Walker and Bösehans, 2016), but they do require widespread charging infrastructure which, at least at the moment in the UK, is severely lagging behind electric vehicle growth goals (Nicholas and Lutsey, 2020). In addition, private cars remain parked roughly 96% of the time, of which 80% are at home and 16% elsewhere (RAC Foundation, 2012) and take up valuable road space that could be reallocated to more space-efficient, active, and sustainable, transportation modes such as bicycles or public transport (Gössling, 2020). The shift to low-carbon modes of transport therefore remains imperative next to measures such as reductions in travel demand, low-carbon fuel policies, uptake of electric vehicles, the improvement of traffic flow, or the redesign of urban space (Barth and Boriboonsomsin, 2008; Gössling, 2020; Mavrin et al., 2020; Plötz et al., 2021). Shared mobility may facilitate the shift to low-carbon modes by maximising 'the utilization of the mobility resources that a society can pragmatically afford, disconnecting their usage from ownership' (Machado et al., 2018). While shared mobility may present a challenge to everyday life logistics (Sopjani et al., 2020), scenario-based

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https://doi.org/10.1016/j.jcmr.2024.100029
Received 9 November 2023; Received in revised form 11 January 2024; Accepted 8 May 2024
Available online 13 May 2024

simulations suggest that a fraction of the current fleet size of cars would be sufficient to meet travel demand (Ciari and Becker, 2017), reinforcing the need for more shared vehicles, benefitting both society and the environment.

Shared mobility modes, such as shared electric or conventional cars, bicycles, cargo-bicycles, and scooters, may offer great potential for carbon reduction, particularly if replacing trips by private car (Fukushige et al., 2021; Zhou et al., 2023). In the light of declining young driver numbers (Chatterjee et al., 2018), shared mobility modes also offer the potential to delay or prevent car dependence, particularly among younger people who are 'car sceptics' and have low interest in car ownership (Sigurdardottir et al., 2014). Moreover, by offering users a wide array of flexible mobility options, shared mobility increases the potential for multimodal mobility (Willing et al., 2017). The introduction of shared mobility may also lead to less biased mode choices, thus reducing overall transport-related energy consumption (Becker et al., 2020). However, there is only limited evidence to date of the effectiveness of shared mobility modes acting as either a potential addition to or substitute for trips by private car. Well-designed pilot studies with conclusive and reliable data are scarce, and evidence is emerging that shared mobility may complement rather than reduce possession and use of a car (Storme et al., 2020). In addition, shared mobility may also affect the use of public transport and active modes, with previous research indicating that shared (e-)bikes may substitute trips otherwise undertaken by walking, private bicycle, or public transport (Bieliński et al., 2021; Ma et al., 2020). Hence, in the present study, the authors sought to investigate the mode substitution patterns of active shared mobility users across a range of shared mobility modes, thus establishing their potential as a sustainable transport alternative.

To this end, the mode substitution patterns, trip and user characteristics of 602 self-reported shared mobility users were examined as part of the eHUBS project (see also Bösehans et al., 2023a, 2023b, 2023c). The eHUBS project (2019–2022) has piloted shared electric mobility hubs - offering a combination of at least two types of shared electric vehicles including e-bikes, e-cargobikes and e-cars - in a range of small- to large-sized cities spanning several EU countries (Belgium, Germany, France, and the Netherlands) and the UK (England). The project was extended to cover additional regions including Wallonia (Belgium), Dublin (Ireland), and Inverness (Scotland), known as CAPS (2021–2023). The novelty of eHUBS lies in the diverse offer of shared electric vehicles, thus offering users a greater range of available alternatives compared to single mode offerings. While the hub locations serve as central agglomeration points for the shared electric vehicles, chosen by local authorities, users must register with partnered shared mobility providers that provide their vehicles at the hub. As such, eHUBS are suited to both casual and regular shared mobility users, with no need for a monthly subscription. In this study, shared mobility users both with and without experience of using eHUBS were invited to complete a survey about their shared mobility use.

The remainder of this paper is structured as follows: Section 2 reviews recent literature on mode substitution among shared mobility users, whereas Section 3 introduces the method of the current study including a comparison between shared mobility users and non-users. Section 4 presents the findings of our investigation with a discussion of the results and conclusions being provided in Section 5.

2. Review of literature on mode substitution

Numerous studies on shared mobility have reported mixed results with regard to substituting trips by private car or other transport modes (see Table 1). Below, evidence of the effectiveness of different types of shared (electric) vehicles is reviewed with regard to their mode substitution potential.

i. *Bike sharing.* In general, it has been reported that demographic factors – such as gender, age, income, and household size – as well as travel related factors –including type of trip, duration/ distance, and vehicle ownership – all play significant roles in bike-sharing usage and mode substitution decisions (Barbour et al., 2019, Fukushige et al., 2021). However, research on bike sharing has suggested that users not only substitute the use of the private car, but also walking, their own bicycle, as well as

Table 1
Shared mobility literature with findings related to mode substitution.

Study	Mode	Study context/participants	Method	Predictors / Relevant findings
Barbour et al. (2019)	Bike	Web-based survey to collect data on the bikesharing usage of registered bikesharing users.	Random parameters logit model	Gender, age, income, household size, commute type and length, and vehicle ownership all played significant roles in bikesharing usage and modal substitution decisions.
Bieliński et al. (2021)	Bike	Data from two surveys: before and after the introduction of MEVO e-bikes in Tricity region	Double-hurdle model	Electric bike rides did not function as a substitute for car trips. Shared e-bikes were used by residents as a substitute for public transportation or as a first/last mile of transport to/from public transportation stops.
Ma et al. (2020)	Bike	City of Delft, medium-sized city with approximately 100,000 inhabitants	Binary logit models	Bike-sharing users reduced walking, the use of private bicycle, bus/ tram, and car. Male and multimodal commuters are more likely to use dockless bike-sharing.
Martin and Shaheen (2014)	Bike	2011 survey of annual members of Capital Bikeshare in Washington DC and Nice Ride Minnesota in Minneapolis	Ordinal regression model	Common attributes associated with shifting toward public transit [as a result of bike sharing] include increased age, being male, living in lower density areas, and longer commute distances.
Christoforou et al. (2021)	e-scooters	Face-to-face road survey among e-scooter (ES) users in Paris	Quantitative analysis	Users shifted mainly from walking and public transportation (72%), and few have increased their total mobility by making new trips (6%)
James et al. (2019)	e-scooters	Survey of 181 e-scooter riders and non-riders and observational study	Quantitative analysis	e-scooter trips in Rosslyn replaced trips otherwise taken by Uber, Lyft, or a taxi (39%), foot (33%), bicycle (12%), bus (7%), or car (7%).
Amatuni et al. (2020)	Car	Three case studies including San Francisco, Calgary, and the Netherlands	LCA-based model	CS participation reduces annual mobility emissions by 3–18% for the average member. Yet, merely using CS over the private car will not introduce lower total emissions if the total PKT demand for driving remains constant.
Chapman et al. (2020)	Car	Survey data from both car sharers and non-sharers	Zero-inflated negative binomial regression	According to our results, only by assuming that car-sharing has a large effect on car-ownership (i.e., the weak cut-off group) will car-sharing lead to a statistically significant reduction in car-use.
Becker and Rudolf (2018)	Cargobike	30 Free Cargo-Bikesharing initiatives sent city-specific survey link to their registered users via email	Quantitative analysis	Results show that 46 percent of respondents maintain that they would have made the trip by car in the absence of a cargo-bike-sharing operator, indicating the high potential of cargo-bikesharing to reduce car usage.

bus/tram (Ma et al., 2020), with mode choice models providing comparable results (Reck et al., 2022). Similarly, electric bike rides did not substitute trips by private car, but rather acted as a substitute for public transport, although they may serve as a first- and last-mile alternative for the latter, thus increasing the catchment area of public transport considerably (Bieliński et al., 2021). In a similar vein, Martin and Shaheen (2014) suggested that bike sharing facilitates a shift to public transport. In particular, the authors found that common attributes associated with shifting toward public transit [as a result of bike sharing] include increased age, being male, living in lower density areas, and longer commute distances. With respect to other shared modes, the findings also are mixed.

ii. *E-scooters.* A study of e-scooter users in Paris suggests that 72% of interviewed users previously either walked or used public transport (Christoforou et al., 2021). Similarly, a study in the US reported that e-scooters replaced trips otherwise taken by Uber, Lyft, or a taxi (39%), foot (33%), bicycle (12%), bus (7%), or car (7%) (James et al., 2019). In a mode choice model by Reck et al. (2022), shared e-scooters were predicted to replace mostly walking (51%), followed by trips using public transport (19%), bicycle (13%), and car (12%). Yet, while the potential of e-scooters to replace trips by private car may be limited, e-scooters may substitute trips by ride-hailing/taxi (Guo and Zhang, 2021; James et al., 2019).
iii. *Car sharing.* Similar to other shared modes, car sharing competes with public transport and cycling (Carrone et al., 2020), although it may also complement the latter (Ceccato and Diana, 2021). Car sharing has been shown to have a positive impact on users' annual mobility emissions, with the caveat that, if the total Passenger Kilometre Travel (PKT) demand for driving remains constant, using car sharing over the private car will not reduce emissions or, in rare cases, may even increase emissions (Amatuni et al., 2020). Likewise, further research on car sharing concluded that car sharing will only significantly reduce car use if it also has a large effect on car-ownership (Chapman et al., 2020).
iv. *Cargobike sharing.* Probably the most promising results in terms of car substitution have been reported in relation to shared cargobikes. For instance, in a study of free cargobike sharing schemes, almost half of shared cargobike users reported that they would have used their private car in the absence of the shared cargobike service (Becker and Rudolf, 2018). At the same time, however, the use of cargobike sharing has been shown to be strongly associated with the use of active travel modes, particularly cycling, indicating that those most interested in cargobike sharing often already travel by sustainable means (Hess and Schubert, 2019).

In summary, the evidence surrounding shared mobility and mode substitution, particularly regarding private car use, remains largely inconclusive. On the one hand, due to little variation in the local contexts in which studies were conducted (mostly cities in developed Western countries with good infrastructure for active travel), estimates of mode substitution elasticities may prove to be too broad. On the other hand, methodological limitations (e.g., reliance on self-report survey data or Stated Preference experiments) may limit the reliability of estimates. The present study, therefore, provides new evidence on mode substitution patterns using an online survey conducted among shared mobility users and non-users as part of the eHUBS project, which is focused on the provision of electric shared mobility hubs in varying geographical contexts – in particular, cities located in countries with a strong (e.g., Belgium, Netherlands) versus countries with a weak cycling culture (e.g., England, France). A novelty of our study lies in the simultaneous consideration of a multitude of chosen shared mobility options and substituted alternatives, across different parts of the EU and UK, as well as a closer inspection of substituted trip characteristics. Also, given that this study captured a sample from countries with high as well as a low cycling culture, both consistency and new insights emerged. The methodology is detailed in Section 3. First, the survey design and data collection process are outlined (Section 3.1), followed by a preliminary comparison between the demographic and travel related profile between shared mobility users and non-users (Section 3.2), so as to highlight any differences in characteristics between the two sampled groups.

3. Method

3.1. Survey design and data collection

Survey data was acquired in two waves using two independent surveys with overlapping content. As the surveys were not identical, only common content of the two surveys will be considered here. The first wave of data collection ($N = 1025$) was conducted between September 2021 and early January 2022 in six pilot cities of the eHUBS project including Amsterdam, Arnhem, Nijmegen (Netherlands), Leuven (Belgium), Dreux (France), Kempten (Germany), and Manchester (UK). The second wave of data ($N = 485$) was collected during February 2023 in Dublin (Ireland), Inverness (Scotland), and Manchester (UK), as part of Capitalisation Project (CAPS), which is an extension to the original eHUBS project.

Tailored versions of the online survey were distributed either via the cities' own distribution channels (e.g., newsletters and social media), shared mobility providers, or via an online survey panel (Amsterdam and Manchester only). The survey included sections for both users and non-users of shared mobility, covering amongst others:

i. **Demographic information** including the respondent's age, gender, city/country of residence, number of adults/children living in the household, highest education level achieved, current (employment) status, and annual household income.
ii. **Car use details** including possession of a driver's licence, frequency of short trips by car (i.e., up to 6 miles/10 km), car fuel type, and whether respondents usually are the car driver or passenger.
iii. **General travel** including traveller identity (mode) and availability of different types of vehicles in the household (i.e., electric or non-electric cars, bicycles, cargobikes and scooters).
iv. **Shared mobility use (users only)** usual trip type (i.e., mostly one-way versus mostly round-trip), importance of shared mobility to daily trip making, combined use of shared mobility with public transport.
v. **Last trip details (users only)** including purpose, distance travelled, frequency, and likelihood of making the trip if shared mobility had not been an option.

Mode substitution patterns were measured by asking self-reported shared mobility users to recall their last trip using shared mobility and to indicate which shared mode they had chosen on the occasion, as well as the alternative mode they would have chosen if shared mobility had not been an option. It should be noted here that, while e-scooters were included in the present study, e-scooters are not available via eHUBS, which focus on the provision of e-bikes, e-cargobikes, and e-cars. The majority of the total sample ($N = 1510$) were not currently using shared mobility ($n = 908$, 60%), whereas two in five respondents reported using publicly shared vehicles *at least once a month* and were thus classified as *shared mobility users* ($n = 602$, 40%). Proportionally, England ($n = 213$, 35%), the Netherlands ($n = 141$, 23%), and Belgium ($n = 87$, 14%), represented the highest proportions of shared mobility users, totalling 72% ($n = 441$) of the sample of shared mobility users. When interpreting the study findings, the reader should bear in mind that cities in the Netherlands and Belgium have comparatively high levels of cycling – for instance, in Amsterdam, the mode share of cycling in the city is 38%

(Iamsterdam, 2014), whereas it is 41% in Leuven (Buczynski, 2019). Table 2 summarises the base mode shares in each of the six countries where data was obtained.

3.2. Shared mobility user and non-user sample comparison

In total, 1510 valid survey responses were received, namely 908 non-users [eHUBS: 753 / CAPS: 155] and 602 users [eHUBS: 272 / CAPS: 330]). The population of non-users was comparable to the EU average based on age and gender. That is, 25- to 54-year-olds represented 58% of non-users, whereas this group accounts for 42% of the EU population. Worthy of note is that the latter figure is based on the total EU population which includes 0–24-year-olds. It is clear that the over-representation of middle-aged adults (i.e., 25–54 years) in our study is because only adults (i.e., 18 years or older) were eligible to participate in our study. Similarly, respondents aged 55 and above accounted for 38% of non-users, whereas this group accounts for 32% of the EU population. Notably, 18% of non-users reported as being retired, which is consistent with the proportion of respondents at or above the legal retirement age (19% were 65 years or older), corresponding to the EU-average of this age group (i.e., 19% are 65 years or older). In terms of gender, there was a slightly higher proportion of male respondents among non-users (52%), compared to the EU average (49%). With regard to education, non-users were more likely to possess a university degree than is typical in the EU on average (67% vs 40%). Compared to non-users and the EU average, shared mobility users, on the other hand, were even more likely to be male (58%), to be 25–54-year-olds (80%), and to have completed tertiary education (i.e., possess a university degree; 76%), confirming findings from previous research (e.g., Reck and Axhausen, 2021).

The Pearson's chi-squared test of homogeneity identifies statistically significant differences in the distributions on a single variable of interest between two or more independent samples (Franke et al., 2012). The null hypothesis assumes that the proportions between the two (or more) groups or samples are the same, whereas the alternative hypothesis proposes that the proportions are different. The obtained test statistic is compared against a critical value from the chi-square distribution with the product of (r - 1) and (c – 1) degrees of freedom, where r is the number of rows and c the number of columns in the table. The chi-square test itself, however, only provides information on statistical differences in observed and expected proportions across the whole contingency table rather than between specific groups represented in rows or columns (Franke et al., 2012). Hence, column-proportion-based differences between the sample of shared mobility users and non-users were tested using follow-up z-tests at common levels of statistical significance ($\alpha = .05$) with Bonferroni adjusted p-values in SPSS Version 29. Below, we report the results of the chi-squared tests and comparison between shared mobility users and non-users.

As might be expected, there were large discrepancies in terms of the observed and expected counts for demographic variables (see Table 3), including respondents' age, with significantly higher observed versus expected proportions of younger shared mobility users ($\chi^2 = 180.32$, $df = 6$, $p < 0.001$; *Cramer's* $V = 0.35$). Comparing shared mobility users to non-users, column-proportion-based tests revealed that a statistically significant greater proportion of shared mobility users were between 18 and 44 years old (72%) compared to non-users (41%; $p < 0.05$). On the

Table 2
Modal shares in cities/countries where data was collected.

Country	% Private	% Active	% Public
Netherlands[a]	37	38	25
Belgium[b]	68	21	11
France[c]	63	26	11
Ireland[d]	59	25	15
Scotland[e]	66	23	9
England[f]	60	33	7

[a] http://www.iamsterdam.com/en-GB/Media-Centre/city-hall/dossier-cycling/Cycling-facts-and-figures (Figures are for Amsterdam only)
[b] Mobility Barometer — VIAS (vias-modalsplit.be) (based on share of travelled km)
[c] Comment les Français se déplacent-ils en 2019 ? Résultats de l'enquête mobilité des personnes | Données et études statistiques (developpement-durable.gouv.fr)
[d] Dublin_GlobalCityMobility_WEB (deloitte.com) (Figures are for Dublin only)
[e] Personal Travel | Transport Scotland
[f] National Travel Survey 2021: Mode share, journey lengths and public transport use - GOV.UK (www.gov.uk)

Table 3
Demographic comparison of non-users and users of shared mobility where a * denotes a statistically significant difference at 95% confidence level.

Variable	Category (incl. EU average)[a,b]		Non-users ($N = 908$)	Users ($N = 602$)	Pairwise comp.
Age	18–24	26%[c]	44 / 5%	52 / 9%	*
	25–34	42%	143 / 16%	214 / 36%	*
	35–44		179 / 20%	164 / 27%	*
	45–54		196 / 22%	103 / 17%	*
	55–64	13%	172 / 19%	45 / 7%	*
	65–74	19%	117 / 13%	20 / 3%	*
	75 or older		56 / 6%	3 / 1%	*
Gender	Male	49%	474 / 52%	347 / 58%	*
	Female	51%	426 / 47%	248 / 41%	*
	Other		6 / 1%	4 / 1%	-
Country	Netherlands		531 / 58%	141 / 23%	*
	Belgium		134 / 15%	87 / 14%	-
	France		52 / 6%	14 / 2%	-
	Ireland		29 / 3%	63 / 10%	*
	Scotland		65 / 7%	75 / 12%	*
	England		75 / 8%	213 / 35%	*
	Other		22 / 2%	9 / 4%	-
N Adults	1		264 / 29%	148 / 25%	-
	2		486 / 54%	358 / 61%	*
	3		85 / 10%	45 / 7%	-
	4 or more		63 / 7%	40 / 7%	-
N Children	0		619 / 71%	362 / 61%	*
	1		118 / 13%	101 / 17%	-
	2		96 / 11%	95 / 16%	*
	3 or more		44 / 5%	35 / 6%	-
Highest degree	School		197 / 22%	72 / 12%	*
	Professional		79 / 9%	60 / 10%	-
	University[d]		609 / 67%	457 / 76%	*
	Prefer not to say/ No school		21 / 2%	12 / 2%	-
Current status	School/Trainee		7 / 1%	9 / 2%	-
	Student		31 / 3%	31 / 5%	-
	Part-time employed		118 / 13%	55 / 9%	*
	Full-time employed		379 / 42%	385 / 64%	*
	Self-employed		80 / 9%	56 / 9%	-
	Unemployed		30 / 3%	18 / 3%	-
	Family		27 / 3%	6 / 1%	*
	Retired		162 / 18%	23 / 4%	*
	Other		25 / 3%	4 / 1%	*
Income	< 24.000€		130 / 14%	68 / 11%	-
	24.000€-47.999€		247 / 27%	171 / 28%	-
	48.000€-71.999€		184 / 20%	128 / 21%	-
	72.000€-95.999€		103 / 11%	85 / 14%	-
	96.000€-120.000€		55 / 6%	52 / 9%	-
	> 120.000€		29 / 3%	43 / 7%	*
	Prefer not to say		157 / 17%	51 / 9%	*

[a] Retrieved January 2024 from European Union Age structure - Demographics (indexmundi.com).
[b] Retrieved January 2024 from Gender statistics - Statistics Explained (europa.eu).
[c] Please note that this figure includes all age groups from 0 to 24 years of age.
[d] The average for completing tertiary education in the EU was 40% for 25–34-year-olds in 2022 based on Educational attainment statistics - Statistics Explained (europa.eu).

other hand, no statistically significant differences between observed and expected counts were identified for gender ($\chi^2 = 4.62$, $df = 2$, *ns*), with a fairly even distribution of male and female respondents among non-users, although pairwise comparisons did suggest a statistically significant difference between shared mobility users and non-users ($p < 0.05$), with the former evidencing a higher proportion of males (58% vs 52%) and lower proportion of females (41% vs 47%), respectively.

Similar to the results for gender, the overall chi-squared test for the number of adults in the household was non-significant ($\chi^2 = 6.50$, $df = 3$, *ns*). Yet, column-based comparisons revealed that shared mobility users were more likely to live in a household with two adults compared to non-users (61% vs 54%; $p < 0.05$). A significant difference did emerge, however, for the expected and observed number of children in the household ($\chi^2 = 15.39$, $df = 3$, $p < 0.01$; *Cramer's V* = 0.10). Pairwise comparisons suggested that non-users were statistically significant more likely to live in a household with no children (71%) compared to users (61%; $p < 0.05$), whereas the latter were statistically significant more likely to live in a household with two children compared to non-users (16% vs 11%; $p < 0.05$). Furthermore, the results suggested a significant difference of observed and expected proportions for education ($\chi^2 = 24.79$, $df = 6$, $p < 0.001$, *Cramer's V* = 0.13) with shared mobility users being more likely to hold a university degree than non-users (76% vs 67%, $p < 0.05$), while the latter were more likely to report school education as their highest level of education (22% vs 12%, $p < 0.05$).

In terms of current occupation, significant differences in expected and observed frequencies also were identified ($\chi^2 = 117.22$, $df = 10$, $p < 0.001$; *Cramer's V* = 0.29). Between the two samples, shared mobility users were statistically significant more likely to be full-time employed than non-users (64% vs 42%; $p < 0.05$), whereas more non-users reported being retired from work (18% vs 4%), part-time employed (13% vs 9%), or citing home/family as a primary role (3% vs 1%; all $p < 0.05$). Finally, significant differences between observed and expected values were observed in terms of income ($\chi^2 = 40.83$, $df = 6$, $p < 0.001$; *Cramer's V* = 0.17), with non-users being significantly more likely to select 'Prefer not to say' than users (17% vs 9%, $p < 0.05$), and more high-income earners (i.e., ≥ 72.000€) being present among shared mobility users compared to non-users (30% vs 20%, $p < 0.05$).

With reference to Table 4, statistically significant differences between observed and expected values also emerge for possession of a driver's licence ($\chi^2 = 10.28$, $df = 1$, $p < 0.01$, *Cramer's V* = 0.08), albeit not for traveller identity ($\chi^2 = 8.91$, $df = 6$, *ns*). Yet, with respect to differences between shared mobility users and non-users, pairwise comparisons (z-tests) revealed that a statistically significant greater proportion of shared mobility users identified as multimodal compared to non-users (30% vs 25%, $p < 0.05$) and were also more likely to possess a driver's licence (91% vs 86%, $p < 0.05$).

In terms of the travel modes available in the household, statistically significant differences between users and non-users were observed for the number of cars in the household (conventional: $\chi^2 = 49.16$, $df = 4$, $p < 0.001$, *Cramer's V* = 0.18; electric: $\chi^2 = 15.56$, $df = 3$, $p < 0.01$, *Cramer's V* = 0.11), number of bicycles in the household (conventional: $\chi^2 = 24.34$, $df = 4$, $p < 0.001$, *Cramer's V* = 0.13; electric: $\chi^2 = 7.97$, $df = 3$, $p = 0.047$, *Cramer's V* = 0.08), number of cargobikes in the household (conventional: $\chi^2 = 17.75$, $df = 3$, $p < 0.001$, *Cramer's V* = 0.11; electric: $\chi^2 = 11.79$, $df = 3$, $p < 0.01$, *Cramer's V* = 0.09), and number of motorbikes and scooters (electric: $\chi^2 = 20.85$, $df = 3$, $p < 0.001$, *Cramer's V* = 0.12).

Notably, shared mobility users were less likely to either possess a private car (61% vs 77%, $p < 0.05$) or bicycle (78% vs 85%, $p < 0.05$) than non-users, but were more likely to possess a cargobike (9% vs 4%, $p < 0.05$). In terms of electric vehicles, shared mobility users were more likely to possess an electric car (16% vs 9%, $p < 0.05$), e-cargobike (10% vs 5%, $p < 0.05$), and electric motorbike or scooter (9% vs 4%, $p < 0.05$) compared to non-users. The latter, on the other hand, were more likely to possess two or more e-bikes compared to shared mobility users (9% vs 5%, $p < 0.05$).

Table 4
Traveller identity and driving licence/vehicle availability among non-users and users of shared mobility (statistical significance as in Table 3).

Variable	Category	Non-users (*N* = 908)	Users (*N* = 602)	Pairwise comp.
Identity	Car driver	290 / 32%	166 / 28%	-
	Car passenger	27 / 3%	25 / 4%	-
	Cyclist	223 / 25%	136 / 23%	-
	Pedestrian	72 / 8%	44 / 7%	-
	PT user	64 / 7%	45 / 8%	-
	Multi-modal	230 / 25%	183 / 30%	*
Licence	Yes	780 / 86%	550 / 91%	*
	No	128 / 14%	52 / 9%	*
N cars	0	204 / 23%	233 / 39%	*
	1	500 / 56%	247 / 41%	*
	2 or more	187 / 21%	120 / 20%	-
N e-cars	0	738 / 91%	481 / 84%	*
	1	73 / 9%	89 / 15%	*
	2 or more	4 / <1%	4 / 1%	-
N bicycles	0	131 / 15%	131 / 22%	*
	1	216 / 24%	163 / 28%	-
	2	211 / 24%	124 / 21%	-
	3 or more	332 / 37%	174 / 29%	*
N e-bikes	0	603 / 72%	423 / 74%	-
	1	162 / 19%	121 / 21%	-
	2 or more	75 / 9%	29 / 5%	*
N cargobikes	0	803 / 95%	525 / 90%	*
	1	38 / 4%	48 / 8%	*
	2 or more	1 / <1%	8 / 1%	-
N e-cargobikes	0	796 / 95%	523 / 90%	*
	1	40 / 5%	52 / 9%	*
	2 or more	3 / <1%	4 / 1%	-
N moto/scoot	0	738 / 87%	491 / 84%	-
	1	91 / 11%	71 / 12%	-
	2 or more	18 / 2%	20 / 3%	-
N e-moto/ scoot	0	795 / 96%	523 / 91%	*
	1	32 / 4%	49 / 8%	*
	2 or more	- / -	5 / 1%	-

To provide a clearer picture regarding the differences between shared mobility users and non-users, the variables in Tables 3 and 4 were used as predictors in a binary logistic regression analysis to predict which variables increase the likelihood of being a shared mobility user (see Table 5). This analysis revealed that being between 25 and 34 years of age significantly increases the odds for being a shared mobility user (+45%), whereas being between 45 and 64 years of age significantly decreases the odds. Further variables that increase the odds of being a shared mobility user include being full-time employed (+75%), earning a high income (i.e., £100,000/120.000€ or more; +99%), possessing a valid driver's license (+159%), and possessing an electric scooter (+185%). In contrast, factors that (strongly) decrease the odds include having secondary school education (albeit nonsignificant), being retired from work, and owning one or more non-electric private cars.

4. Mode substitution analysis

This section presents the results of general mode substitution patterns (Section 4.1) and with specific attention paid to the characteristics of substituted trips in Section 4.2.

4.1. Mode substitution patterns

Fig. 1 visualises the shared mobility mode chosen by respondents as their last trip along with the substituted modes (i.e., the travel mode that respondents would likely have used if shared mobility had not been an option) see also Table A1 in the appendix. The three most frequently substituted modes included walking or cycling ($n = 191$, 32%), public transport ($n = 148$, 25%), and the private car ($n = 129$, 21%). Other

Table 5
Logistic regression results to predict shared mobility use (N Non-user = 713, Accuracy: 78%; N User = 540, Accuracy: 54%; Nagelkerke R^2 = 0.23).

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
Constant	-0.507	0.229	4.879	1	0.027	0.603		
Age 25–34	0.369	0.160	5.313	1	0.021	1.447	1.057	1.980
Age 45–54	-0.575	0.177	10.564	1	0.001	0.563	0.398	0.796
Age 55–64	-0.691	0.211	10.747	1	0.001	0.501	0.332	0.757
Secondary school education	-0.269	0.186	2.103	1	0.147	0.764	0.531	1.099
Full-time employed	0.558	0.138	16.264	1	<0.001	1.747	1.332	2.290
Retired from work	-1.339	0.281	22.638	1	<0.001	0.262	0.151	0.455
Income => £100,000 / 120.000€	0.686	0.281	5.961	1	0.015	1.987	1.145	3.447
Possesses a valid driver's licence	0.950	0.224	17.999	1	<0.001	2.585	1.667	4.009
Number of Cars = 1	-1.096	0.157	48.607	1	<0.001	0.334	0.246	0.455
Number of Cars = 2	-1.099	0.205	28.638	1	<0.001	0.333	0.223	0.498
Number of Cars = 3 or more	-1.299	0.343	14.296	1	<0.001	0.273	0.139	0.535
Number of eScooters = 1	1.048	0.274	14.657	1	<0.001	2.852	1.668	4.878

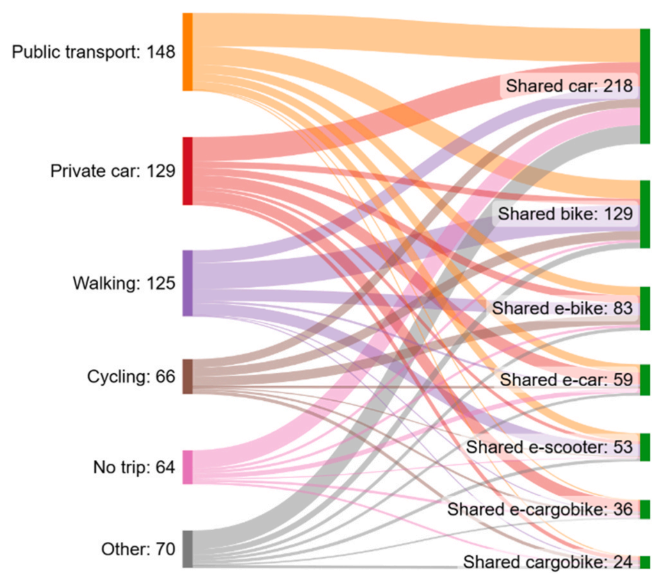

Fig. 1. Substituted (left) and chosen shared (right) mobility modes (n = 602).

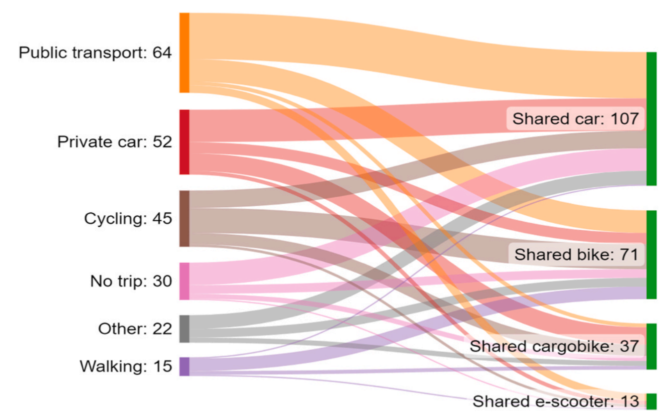

Fig. 2. Mode substitution patterns in the Netherlands and Belgium (*n* = 228).

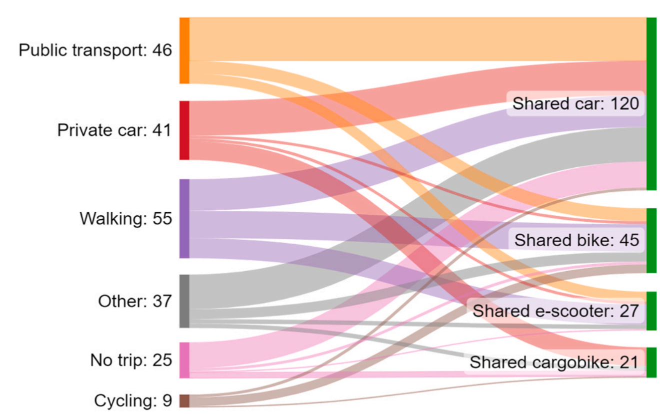

Fig. 3. Mode substitution patterns in England (n = 213).

substituted modes included trips by ride hailing (*n* = 40, 7%), carpooling (*n* = 25, 4%), and motorcycle (*n* = 5, 1%). A further subset of respondents indicated that they would not have made their trip if shared mobility had not been available (*n* = 64, 11%), thus suggesting that these trips were enabled through shared mobility and therefore can be considered as generated trips. Among chosen shared modes (both conventional and electric), shared cars represented the majority (*n* = 277, 46%), followed by shared bicycles (*n* = 212, 35%), and shared cargobikes (*n* = 60, 10%). Likely due to the legal restrictions on the use of e-scooters in the Netherlands and Belgium at the time of data collection, e-scooters represented the smallest proportion of chosen shared modes (*n* = 53, 9%).

Figs. 2 and 3 provide a comparison of mode substitution patterns in two different geographical contexts - the Netherlands and Belgium versus England. A noteworthy difference between the latter is the greater substitution of cycling vs walking trips in the Netherlands and Belgium (20% vs 7%), compared to England, where the reverse is the case (4% vs 26%).

4.2. Substituted trip characteristics

Table A2 (appendix) provides more detailed information on the nature of substituted trips (e.g., trip purpose, length, and frequency), whereas Table A3 (appendix) provides information on the demographic characteristics of users for each of the most commonly substituted modes (i.e., ≥ 10%). Below, the key characteristics of respondents' shared mobility trips are summarised for each substituted mode representing at least 10% of responses.

- **Public transport (*n* = 148, 25% of substituted trips)**. Three major trip purposes emerged for substituted public transport trips including visiting others (30%), commuting (23%), and leisure or tourism (21.5%). A distinguishing feature of substituted public transport trips was their length, as the majority of substituted trips were reported to be seven miles or longer (59%). In terms of chosen alternative modes, shared (e-)cars were the most common choice (53%), followed by shared (e-)bikes (35%) and e-scooters (10%). More than half of respondents also reported using shared modes in combination with public transport (54%). Compared to other groups, a greater proportion of those who had substituted a trip by public transport identified themselves as either public transport or multimodal users (50.5% vs 28.5–42%). In addition, compared to those who either substituted a trip by private car (34%) or bicycle (41%), those choosing shared mobility instead of public transport were more likely to use shared mobility in combination with the latter (54%). There were no notable differences in demographic characteristics between this substituted mode group and other groups.

- **Private car ($n = 129$, 21% of substituted trips)**. Trip purposes varied for substituted car trips, ranging from commuting (25.5%) to leisure or tourism (18.5%), followed by (grocery) shopping and visiting others (both 14%). The primary modes that replaced the private car were either shared (e-)cars (54%), followed by shared (e-) cargobikes (21%) and (e-)bikes (20%). Compared to other substituted modes, a greater proportion of respondents who had substituted a trip by private car identified themselves as car drivers (38% vs 18–31%) and possessed a driver's licence (96% vs 88–89%). Substituted car trips also tended to be somewhat more frequent (i.e., at least 1–2 times per week; 23% vs 9–18%). Similar to public transport, substituted trips tended to be longer in terms of distance (56% seven miles or more). Finally, private car users were the least likely to use shared modes in combination with public transport (34%) compared to other substituted mode groups (41–54%). In terms of respondents' demographic characteristics, a higher proportion of males substituted private car trips compared to females (67% vs 33%) – the largest observed difference in terms of gender for all substituted modes. Also, 90% of those who substituted a trip by private car reported being employed (vs 82–84% in other groups) and 57% reported having a least one child living in the household, which is a substantially higher proportion compared to the remaining groups (25–42%).
- **Walking ($n = 125$, 21% of substituted trips)**. As might be expected, substituted walking trips generally tended to be shorter (i.e., between 1 and 3 miles) than other substituted modes (38% vs 12–32%) and represented the highest proportion of respondents identifying themselves as pedestrians (16% vs 3–9.5%), although the most common traveller identity was car driver (31%). The most common trip purpose for shared mobility trips replacing walking was leisure or tourism (37%), with shared (e-) bikes accounting for more than half of the chosen shared mobility alternatives (57%), followed by shared (e-)cars (22%) and e-scooters (18%). In terms of demographic characteristics, it is noteworthy that younger respondents (i.e., 18–34-year-olds) represented the largest proportion for substituted walking trips (54% vs 34.5–44.5%). Moreover, 59% of respondents identified as male and reported being resident in either England (44%), Ireland (22%), or Scotland (20%). Finally, those substituting walking trips also were the least likely to live in a household with children (25% vs 33–57%).
- **Cycling ($n = 66$, 11% of substituted trips)**. The most frequently cited trip purpose for substituted cycling trips was grocery shopping (30%) and the most frequently chosen shared substitutes included shared (e-)bikes (53%), followed by shared (e-)cars (29%), and (e-) cargobikes (15%). As with most other categories, trips tended to follow a round trip pattern (65%) and most respondents indicated they would have made the trip regardless of the availability of shared mobility (74% likely or very likely). Unsurprisingly, of those substituting trips by private bicycle, many identified as cyclists (43%) - the highest proportion among all groups - and most reported their country of residence as either the Netherlands or Belgium (68%). Notably, a third of respondents indicated that shared mobility represents an integral part of their daily mobility (33% vs 21–23% in remaining groups). Apart from country of residence, no major deviations compared to the other groups were observed.
- **No trip ($n = 64$, 11% of substituted trips)**. In total, 11% of shared mobility users indicated that they would not have undertaken their trip if shared mobility had not been an option. This was confirmed by the high proportion of respondents reporting that they would have been (very) unlikely to have made the trip in the absence of shared mobility (78%), which was considerably higher compared to other categories (10–19.5%). The most frequently chosen shared mobility modes consisted of shared (e-)cars (67%), followed by shared (e-) bikes (16%) and (e-)cargobikes (14%). The most common trip purpose of these 'generated' trips was for leisure or tourism (40.5%) and, compared to other groups, the majority of trips tended to be longer (i.e., seven miles or more; 73% vs 32–59%), less frequent (i.e., once per month or less; 72% vs 47–67%), and were more likely to follow a round trip pattern (84.5% vs 56–76%). Generated trips were most likely to be reported from respondents resident in England (39%), followed by the Netherlands (26.5%), and Belgium (20.5%).

5. Discussion

From the analysis of shared mobility user and non-user data, several conclusions can be drawn regarding the demographic profile of shared mobility users, mode substitution patterns, and trip characteristics.

Demographic profile. The demographic profile of shared mobility users showed many parallels with previous research, such as by Reck and Axhausen (2021). In particular, shared mobility users tended to be younger than non-users, were more likely to be more affluent, male, and full-time employed, and tended to be university-educated, supporting the findings of previous research (see also Clewlow and Mishra, 2017). Furthermore, we found that shared mobility users were less likely to possess a conventional private car (see also Reck and Axhausen, 2021), but were more likely to possess an electric car. Contrary to Reck and Axhausen (2021), however, we found that shared mobility users were more likely to live in a two-adult household and/or in a household with children. This research, therefore, suggests that shared mobility may be attractive to car-dependent families. Finally, shared mobility users were more likely to identify as multimodal travellers (see also Ma et al., 2020) and were generally more likely to own an electric or non-electric cargobike.

Mode substitution. With regards to the key question of mode substitution, shared modes tended to replace already sustainable active travel including cycling and walking (32%), in addition to public transport (25%), rather than the private car (21%). Notably, of the substituted car trips, 54% were substituted with either a conventional or electric shared car rather than more active and sustainable alternatives, such as shared (e-)cargobikes (21%) or (e-)bikes (20%). Our findings are thus broadly in line with previous research which indicated that the potential of shared vehicles to substitute the private car is limited (Amatuni et al., 2020; Bieliński et al., 2021; Chapman et al., 2020; Christoforou et al., 2021; James et al., 2019; Ma et al., 2020), at least for now. This, of course, also has direct implications for potential emission savings, which are primarily achieved through reductions in car use. As shared e-mobility modes are more likely to replace already sustainable modes (i.e., public transport, pedal cycle and walk) instead of the private car, their contribution is to exacerbate meeting net-zero targets (see also Felipe-Falgas et al., 2022), and this applies particularly to those shared e-mobility vehicles with a short lifespan, such as e-scooters (Hollingsworth et al., 2019; Reis et al., 2023). Findings are more promising for shared (non-electric) bicycles and private e-scooters, which have been found to decrease emissions (Felipe-Falgas et al., 2022). With regard to the substitution of public transport trips, shared mobility users may be more likely to choose that option because it lowers the overall generalised cost of the trip and so may be more satisfied with the overall journey experience, or may be more likely to travel more frequently by public transport, as a result. On the other hand, public transport may be losing ridership on one service (e.g., a bus accessing a metro station), but the combination with shared mobility may be delivering a travel option which better meets users' needs.

The findings also suggested that a notable proportion of trips (11%) were enabled or generated through shared mobility, and this was particularly the case for shared e-cars and e-cargobikes. These generated (mostly leisure) trips also tended to be the longest, which has obvious implications for carbon emissions. Our findings contradict previous research, which has suggested that car- and bike-sharing are not associated with daily trip generation behaviour (Jiao et al., 2020), although more research is needed in this area.

Trip characteristics. In general, the majority of respondents reported infrequent round-trip-based shared mobility trips, with most trips occurring once per month or less. As might be expected, substituted car and public transport trips tended to be longer (i.e., seven or more miles) than substituted trips by walking or cycling, the majority of which ranged from one to six miles. About one in five respondents (one in three for cyclists) regarded shared mobility as an essential part of their daily mobility. Furthermore, those who substituted trips by either walking or public transport were most likely to use shared mobility in combination with the latter, underlining the potential of shared mobility as a viable first- and last-mile alternative (Shaheen and Chan, 2016). Leisure or tourism and commuting represented the two most common trip purposes, followed by visiting others and grocery shopping (see also Wang and Zhang, 2023, for a more detailed discussion of trip purposes in the case of bike-sharing). For car drivers and cyclists, in particular, respondents' reported traveller identity was in line with their substituted modes – that is, most of those who substituted a trip by private car or bicycle reported identifying themselves as a car driver or cyclist, respectively.

5.1. Limitations and future research

At least three study limitations should be noted. First, mode substitution patterns were measured by asking shared mobility users to recall their last trip using a shared vehicle. Hence, mode substitution patterns were established based on a single trip and thus cannot provide more detailed information about shared mobility users' behaviour over the course of several trips or extended time periods (e.g., weeks or months). The authors did, however, ask respondents to indicate the frequency of their shared mobility trips. Based on this information, it can be concluded that shared mobility trips tend to be infrequent, with most trips occurring only once per month or less. Future research would benefit from a longitudinal rather than cross-sectional design that enables the monitoring of shared mobility users' mode substitution patterns over longer periods of time, particularly with respect to the substitution of trips by private car which seek to contribute most to achieving Net Zero. Second, related to the first limitation, the authors focused on a single self-reported trip with incomplete information about available alternatives. Therefore, the findings should be considered with the knowledge that self-reported data may be prone to errors as respondents are not always capable of recalling all the information relevant to a given question (Paulhus and Vazire, 2007). However, general overlap in conclusions with previous work (e.g., Bieliński et al., 2021) suggests that the conclusions drawn from our research are supported. Furthermore, while the data collected did not include information about all of the shared or non-shared alternatives available to respondents at the time they last used the stated shared mobility service, this information may not have been readily available to respondents themselves. Instead, respondents were asked to focus on the one non-shared alternative they would most likely have chosen if shared mobility had not been an option. While any likely chosen non-shared alternative is merely hypothetical and might not reflect users' actual choice, this is a similar issue that plagues Stated Preference experiments, which are based on purely hypothetical scenarios, even if considering respondents' current mobility behaviour. In contrast to Stated Preference experiments, however, our data is based on self-reports of real-world behaviour, putting potential errors in recall and self-report biases aside. Similarly, while we cannot draw any conclusions about situations in which shared mobility users might have chosen a non-shared alternative over available shared modes, our findings, while limited in scope, nevertheless provide a clear indication of the potential of shared mobility as another non-car alternative. Third, a thorough investigation of the potential carbon emission savings gained by substituting private (petrol or diesel) car trips with (preferably) more sustainable shared electric mobility vehicles was beyond the scope of this paper. Analysing shared mobility trip data with particular attention to the characteristics of substituted modes (e.g., fuel type, age of car, mpg) is therefore of paramount importance for future research aimed at quantifying the potential carbon benefits of shared mobility.

5.2. Conclusions

This study sought to provide novel insights on the mode substitution patterns of active shared mobility users as part of the EU-funded eHUBS/CAPS project. Overall, shared mobility users tended to be younger and less car dependent, underlining the potential of shared mobility to delay or even prevent car dependence for future generations. In terms of mode substitution patterns, the findings indicated that shared (electric) vehicles were just as likely, perhaps more likely, to be used as a substitute for public transport, cycling and walking, as for the private car. In line with previous research, these findings thus provide a mixed picture with respect to the contribution of shared mobility to net-zero targets. For shared mobility to reach its true potential and deliver a significant contribution to reductions in carbon, it must be fully integrated into the logistics of everyday life, taking into account time and effort requirements. Yet, even in cities with high proportions of active travel, this represents a considerable challenge. More restrictive measures, such as car free zones, increased parking charges, or priority lanes for shared (electric) vehicles may further discourage private car use and encourage the uptake of shared mobility. Looking towards the future, however, shared mobility may grow in importance as younger people are increasingly becoming disenchanted with the tradition of private car ownership. Local authorities and policymakers may facilitate this transition by multiplying the offer of shared (electric) vehicles until reaching a critical mass and promoting the use of shared vehicles through interventions. The latter should include dedicated infrastructure and parking facilities that target specific cohorts of the general population, thus increasing the overall attractiveness of electric shared mobility as a suitable replacement for the private car.

Funding information

This work was supported by the EU-funded eHUBs project (Sponsor: INTERREG NWE, Project number: NWE 826).

CRediT authorship contribution statement

Gustav Bösehans: Conceptualization, Formal analysis, Investigation, Software, Writing – original draft. **Margaret Bell:** Methodology, Supervision, Writing – review & editing. **Dilum Dissanayake:** Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

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.

Data availability

The authors do not have permission to share data.

Appendix

Table A1
Respondents' chosen shared mode (columns) and substituted mode (rows) for their last trip using shared mobility ($N = 602$)

Substituted mode	Shared car	Shared bike	Shared cargo-bike	Shared e-car	Shared e-bike	Shared e-cargo-bike	Shared e-scooter	Total
Walking	24	49	1	4	23	2	22	125
	19%	39%	1%	3%	18%	2%	18%	
Cycling	16	17	6	3	18	4	2	66
	24%	26%	9%	5%	27%	6%	3%	
Motorbike	1	1	1	1	0	1	0	5
	20%	20%	20%	20%	0%	20%	0%	
Private car	46	12	7	23	14	21	6	129
	36%	9%	5%	18%	11%	16%	5%	
Carpooling/lift	8	5	3	3	3	1	2	25
	32%	20%	12%	12%	12%	4%	8%	
Public transport	63	35	2	15	17	1	15	148
	43%	24%	1%	10%	11%	1%	10%	
Ride hailing (e.g., Uber, taxi)	26	5	0	1	3	1	4	40
	65%	13%	0%	3%	8%	3%	10%	
I would not have made the trip	34	5	4	9	5	5	2	64
	53%	8%	6%	14%	8%	8%	3%	
Total	218	129	24	59	83	36	53	602
	36%	21%	4%	10%	14%	6%	9%	

Table A2
Trip characteristics by most commonly substituted modes (> 10%)

Last trip	**Switch 1**	**Switch 2**	**Switch 3**	**Switch 4**	**Switch 5**
Substituted mode	PT	Private car	Walking	Cycling	No trip
Frequency / N	148	129	125	66	64
Driver licence					
Yes	132 / 89%	124 / 96%	110 / 88%	58 / 88%	61 / 95%
No	16 / 11%	5 / 4%	15 / 12%	8 / 12%	3 / 5%
Traveller identity					
Car driver	27 / 18%	49 / 38%	39 / 31%	16 / 25%	15 / 23.5%
Car passenger	6 / 4%	7 / 5%	7 / 6%	-	2 / 3%
Cyclist	32 / 21.5%	31 / 24%	19 / 15%	28 / 43%	14 / 22%
Pedestrian	9 / 6%	4 / 3%	20 / 16%	2 / 3%	6 / 9.5%
Public transport	23 / 15.5%	2 / 1.5%	12 / 10%	1 / 1.5%	1 / 1.5%
Multi-modal	51 / 35%	35 / 27%	27 / 22%	18 / 28%	26 / 40.5%
Trip purpose					
Commuting/work	34 / 23%	33 / 25.5%	20 / 16%	12 / 18%	6 / 9.5%
Grocery shopping	5 / 3.5%	18 / 14%	15 / 12%	20 / 30%	8 / 13%
Shopping general	7 / 5%	8 / 6%	13 / 10%	5 / 7.5%	8 / 13%
Visiting others	44 / 30%	18 / 14%	6 / 5%	8 / 12%	9 / 14.5%
Sports activities	3 / 2%	9 / 7%	5 / 4%	3 / 4.5%	1 / 1.5
Leisure / tourism	32 / 21.5%	24 / 18.5%	46 / 37%	10 / 15%	26 / 40.5%
Going out / night	7 / 5%	4 / 3%	13 / 11%	4 / 6%	1 / 1.5
Other (specify)	16 / 11%	15 / 12%	5 / 4%	4 / 6%	4 / 6.5%
Trip distance					
1–3 miles	30 / 21%	22 / 18%	46 / 38%	20 / 32%	8 / 12%
4–6 miles	31 / 20%	34 / 26%	36 / 30%	18 / 27%	9 / 15%
7 miles or more	86 / 59%	71 / 56%	39 / 32%	26 / 41%	47 / 73%
Trip frequency					
Opm or less	98 / 67%	69 / 54%	77 / 63%	31 / 47%	46 / 72%
2–3 pm	32 / 22%	29 / 23%	23 / 19%	24 / 36%	12 / 19%
1–2 pw	11 / 7%	23 / 18%	13 / 11%	8 / 12%	3 / 4.5%
3–4 pw or more	6 / 4%	6 / 5%	9 / 7%	3 / 4.5%	3 / 4.5%
Trip likelihood					
Very likely	66 / 44.5%	55 / 43%	61 / 49%	24 / 36%	4 / 6.5%
Likely	47 / 32%	43 / 34%	34 / 27%	25 / 38%	2 / 3%
Neither	11 / 7.5%	17 / 13%	13 / 11%	4 / 6%	8 / 12.5%
Unlikely	20 / 13.5%	10 / 8%	14 / 11%	10 / 15%	20 / 31%
Very unlikely	4 / 2.5%	3 / 2%	2 / 2%	3 / 4.5%	30 / 47%
General use					
One-way	49 / 34%	31 / 24%	54 / 44%	23 / 35%	10 / 15.5%
Round trip	96 / 66%	97 / 76%	69 / 56%	42 / 65%	54 / 84.5%
Combine with PT					
Yes	80 / 54%	44 / 34%	64 / 52.5%	27 / 41%	31 / 48.5%
No	68 / 46%	84 / 66%	58 / 47.5%	39 / 59%	33 / 51.5%
SM importance					
Integral part	34 / 23%	27 / 21%	26 / 21%	22 / 33%	15 / 23%
Only as needed	97 / 66%	87 / 68%	81 / 66%	38 / 58%	44 / 69%
Only tried once/Oth	15 / 10%	14 / 11%	16 / 13%	6 / 9%	5 / 8%

Table A3
User characteristics by most commonly substituted modes (> 10%)

Last trip	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
Substituted mode	PT	Private car	Walking	Cycling	No trip
Frequency / N	148	129	125	66	64
Age					
18–24	15 / 10%	11 / 8.5%	14 / 11%	1 / 1.5%	4 / 6.5%
25–34	51 / 34.5%	42 / 32.5%	53 / 43%	22 / 33%	24 / 37.5%
35–44	36 / 24%	38 / 29.5%	28 / 23%	16 / 24%	23 / 36%
45–54	27 / 18%	26 / 20%	13 / 11%	18 / 27%	8 / 12.5%
55–64	11 / 7.5%	10 / 8%	12 / 10%	4 / 6%	2 / 3%
65 or older	8 / 5.5%	2 / 1.5%	4 / 3%	5 / 8%	3 / 4.5%
Gender					
Male	83 / 56%	86 / 67%	73 / 59%	34 / 51.5%	33 / 47.5%
Female	63 / 42.5%	42 / 33%	50 / 40%	32 / 48.5%	30 / 52.5%
Other	2 / 1.5%	-	1 / 1%	-	-
Country					
England	46 / 31%	41 / 32%	55 / 44%	9 / 13.5%	25 / 39%
Ireland	16 / 11%	11 / 8.5%	27 / 22%	2 / 3%	4 / 6.5%
Scotland	16 / 11%	19 / 15%	25 / 20%	7 / 11%	4 / 6.5%
Netherlands	40 / 27%	36 / 28%	9 / 7%	23 / 35%	17 / 26.5%
Belgium	24 / 16%	16 / 12%	6 / 5%	22 / 33%	13 / 20.5%
Other	4 / 3%	6 / 5%	2 / 2%	3 / 4.5%	1 / 1%
N Adults					
1	38 / 26%	22 / 17%	36 / 30%	16 / 25%	16 / 26%
2	87 / 60%	87 / 69%	63 / 52%	41 / 64%	37 / 60%
3 or more	21 / 14%	18 / 14%	23 / 19%	7 / 11%	9 / 14%
N Children					
0	98 / 67%	55 / 43%	91 / 75%	37 / 58%	41 / 65%
1	26 / 18%	25 / 19.5%	17 / 14%	10 / 16%	9 / 14.5%
2 or more	22 / 15%	48 / 37.5%	14 / 11%	17 / 26%	13 / 20.5%
Education					
School	20 / 13.5%	11 / 8.5%	19 / 15%	5 / 7.5%	7 / 11%
Professional	15 / 10%	11 / 8.5%	14 / 11%	5 / 7.5%	9 / 14%
University	112 / 75.5%	104 / 81%	89 / 71%	54 / 82%	48 / 75%
Prefer not/No school	1 / 1%	3 / 2%	2 / 2%	2 / 3%	-
Current status					
School/Trainee	-	2 / 2%	2 / 2%	2 / 3%	1 / 1.5%
Student	11 / 8%	3 / 2%	10 / 8%	1 / 1.5%	2 / 3%
Employed	119 / 82.5%	116 / 90%	100 / 82%	54 / 84%	53 / 83%
Unemployed/Family	6 / 4%	1 / 1%	6 / 5%	2 / 3%	4 / 6.5%
Retired/Other	8 / 5.5%	4 / 3%	4 / 3%	5 / 8%	3 / 4.5%
Income					
< 24.000€	19 / 13%	10 / 8%	17 / 14%	8 / 12%	8 / 13%
24.000–47.999€	42 / 28.5%	34 / 26%	36 / 29%	19 / 29%	17 / 27%
48.000–71.999€	31 / 21%	25 / 19%	32 / 26%	15 / 23%	13 / 20.5%
72.000–95.999€	24 / 16%	26 / 20%	13 / 11%	5 / 7.5%	6 / 9.5%
96.000–120.000€	10 / 7%	16 / 12%	9 / 7%	4/ 6%	5 / 8%
> 120.000€	7 / 5%	12 / 9%	9 / 7%	3 / 4.5%	7 / 11%
Prefer not to say	14 / 9.5%	6 / 5%	8 / 6%	12 / 18%	7 / 11%

References

Amatuni, L., Ottelin, J., Steubing, B., Mogollón, J.M., 2020. Does car sharing reduce greenhouse gas emissions? Assessing the modal shift and lifetime shift rebound effects from a life cycle perspective. J. Clean. Prod. *266*, 121869.

Barbour, N., Zhang, Y., Mannering, F., 2019. A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. J. Transp. Health *12*, 253–262.

Barth, M., Boriboonsomsin, K., 2008. Real-world carbon dioxide impacts of traffic congestion. Transp. Res. Rec. *2058* (1), 163–171.

Becker, H., Balac, M., Ciari, F., Axhausen, K.W., 2020. Assessing the welfare impacts of Shared Mobility and Mobility as a Service (MaaS). Transp. Res. Part A: Policy Pract. *131*, 228–243.

Becker, S., Rudolf, C., 2018. Exploring the potential of free cargo-bikesharing for sustainable mobility. GAIA – Ecol. Perspect. Sci. Soc. *27* (1), 156–164.

Bieliński, T., Kwapisz, A., Ważna, A., 2021. Electric bike-sharing services mode substitution for driving, public transit, and cycling. Transp. Res. Part D: Transp. Environ. *96*, 102883.

Bösehans, G., Bell, M., Thorpe, N., Liao, F., Homem de Almeida Correia, G., Dissanayake, D., 2023a. eHUBs—Identifying the potential early and late adopters of shared electric mobility hubs. Int. J. Sustain. Transp. *17* (3), 199–218.

Bösehans, G., Bell, M., Thorpe, N., Dissanayake, D., 2023b. Something for every one?-An investigation of people's intention to use different types of shared electric vehicle. Travel Behav. Soc. *30*, 178–191.

Bösehans, G., Kavta, K., Bell, M.C., & Dissanayake, D. (2023c). Exploring the potential of shared electric vehicles from e-mobility hubs as an alternative for commute and food shopping trips. *IET Intelligent Transport Systems*.

Buczynski, A. (2019). 32% more Cycling in one Year after Eliminating through Car Traffic from the Centre of Leuven. Retrieved October 5, 2023, from ⟨https://ecf.com/news-and-events/news/32-more-cycling-one-year-after-eliminating-through-car-traffic-centre-leuven⟩.

Carrone, A.P., Hoening, V.M., Jensen, A.F., Mabit, S.E., Rich, J., 2020. Understanding car sharing preferences and mode substitution patterns: a stated preference experiment. Transp. Policy *98*, 139–147.

Ceccato, R., Diana, M., 2021. Substitution and complementarity patterns between traditional transport means and car sharing: a person and trip level analysis. Transportation *48*, 1523–1540.

Chapman, D.A., Eyckmans, J., Van Acker, K., 2020. Does car-sharing reduce car-use? An impact evaluation of car-sharing in Flanders, Belgium. Sustainability *12* (19), 8155.

Chatterjee, K., Goodwin, P., Schwanen, T., Clark, B., Jain, J., Melia, S., Middleton, J., Plyushteva, A., Ricci, M., Santos, G. and Stokes, G. (2018). Young People's Travel – What's Changed and Why? Review and Analysis. Report to Department for Transport. UWE Bristol, UK. ⟨www.gov.uk/government/publications/young-peoples-travel-whats-changed-and-why⟩.

Christoforou, Z., de Bortoli, A., Gioldasis, C., Seidowsky, R., 2021. Who is using e-scooters and how? Evidence from Paris. Transp. Res. Part D: Transp. Environ. *92*, 102708.

Ciari, F., Becker, H., 2017. How disruptive can shared mobility be? A scenario-based evaluation of shared mobility systems implemented at large scale. In Disruptinmobility. Springer, Cham, pp. 51–63.

Clewlow, R., & Mishra, G.S. (2017). Shared mobility: Current adoption, use, and potential impacts on travel behavior. *Transportation Research Board 96th Annual Meeting* (No. 17-05729).

Iamsterdam (2014). Cycling facts and figures. Retrieved October 5, 2023, from ⟨https://web.archive.org/web/20140512214416/http:/www.iamsterdam.com/en-GB/Media-Centre/city-hall/dossier-cycling/Cycling-facts-and-figures⟩.

Felipe-Falgas, P., Madrid-Lopez, C., Marquet, O., 2022. Assessing environmental performance of micromobility using lca and self-reported modal change: the case of shared e-bikes, e-scooters, and e-mopeds in barcelona. Sustainability *14* (7), 4139.

Fukushige, T., Fitch, D.T., Handy, S., 2021. Factors influencing dock-less E-bike-share mode substitution: Evidence from Sacramento. Calif. Transp. Res. Part D: Transp. Environ. *99*, 102990.

Franke, T.M., Ho, T., Christie, C.A., 2012. The chi-square test: often used and more often misinterpreted. Am. J. Eval. *33* (3), 448–458.

Gössling, S., 2020. Why cities need to take road space from cars-and how this could be done. J. Urban Des. *25* (4), 443–448.

Guo, Y., Zhang, Y., 2021. Understanding factors influencing shared e-scooter usage and its impact on auto mode substitution. Transp. Res. Part D: Transp. Environ. *99*, 102991.

Hess, A.K., Schubert, I., 2019. Functional perceptions, barriers, and demographics concerning e-cargo bike sharing in Switzerland. Transp. Res. Part D: Transp. Environ. *71*, 153–168.

Hollingsworth, J., Copeland, B., Johnson, J.X., 2019. Are e-scooters polluters? The environmental impacts of shared dockless electric scooters. Environ. Res. Lett. *14* (8), 084031.

James, O., Swiderski, J.I., Hicks, J., Teoman, D., Buehler, R., 2019. Pedestrians and e-scooters: an initial look at e-scooter parking and perceptions by riders and non-riders. Sustainability *11* (20), 5591.

Jiao, J., Bischak, C., Hyden, S., 2020. The impact of shared mobility on trip generation behavior in the US: Findings from the 2017 National Household Travel Survey. Travel Behav. Soc. *19*, 1–7.

Ma, X., Yuan, Y., Van Oort, N., Hoogendoorn, S., 2020. Bike-sharing systems' impact on modal shift: A case study in Delft, the Netherlands. J. Clean. Prod. *259*, 120846.

Machado, C.A.S., de Salles Hue, N.P.M., Berssaneti, F.T., Quintanilha, J.A., 2018. An overview of shared mobility. Sustainability *10* (12), 4342.

Martin, E.W., Shaheen, S.A., 2014. Evaluating public transit modal shift dynamics in response to bikesharing: a tale of two US cities. J. Transp. Geogr. *41*, 315–324.

Mattioli, G., Roberts, C., Steinberger, J.K., Brown, A., 2020. The political economy of car dependence: a systems of provision approach. Energy Res. Soc. Sci. *66*, 101486.

Mavrin, V., Magdin, K., Shepelev, V., Danilov, I., 2020. Reduction of environmental impact from road transport using analysis and simulation methods. Transp. Res. Procedia *50*, 451–457.

Nicholas, M., Lutsey, N., 2020. Quantifying the electric vehicle charging infrastructure gap in the United Kingdom. ICCT, London, UK.

Paulhus, D.L., Vazire, S., 2007. The self-report method. In: Robins, R.W., Fraley, R.C., Krueger, R.F. (Eds.), Handbook of Research Methods in Personality Psychology, 1st ed. The Guilford Press, pp. 224–239.

Plötz, P., Wachsmuth, J., Gnann, T., Neuner, F., Speth, D., & Link, S. (2021). Net-Zero-Carbon Transport in Europe until 2050—Targets, Technologies and Policies for a Long-Term EU Strategy. *Karlsruhe: Fraunhofer Institute for Systems and Innovation Research ISI*. Available online: ⟨https://www.isi.fraunhofer.de/en.html⟩ (Accessed 12 January 2023).

RAC Foundation (October 2012). Keeping the Nation Moving. Facts on Parking. Retrieved October 3, 2023, from ⟨https://www.racfoundation.org/wp-content/uploads/2017/11/parking_fact_sheet.pdf⟩.

Reck, D.J., Axhausen, K.W., 2021. Who uses shared micro-mobility services? Empirical evidence from Zurich. Switz. Transp. Res. Part D: Transp. Environ. *94*, 102803.

Reck, D.J., Martin, H., Axhausen, K.W., 2022. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transp. Res. Part D: Transp. Environ. *102*, 103134.

Reis, A.F., Baptista, P., Moura, F., 2023. How to promote the environmental sustainability of shared e-scooters: a life-cycle analysis based on a case study from Lisbon. Port. J. Urban Mobil. *3*, 100044.

Shaheen, S., Chan, N., 2016. Mobility and the sharing economy: Potential to facilitate the first-and last-mile public transit connections. Built Environ. *42* (4), 573–588.

Sigurdardottir, S.B., Kaplan, S., Møller, M., 2014. The motivation underlying adolescents' intended time-frame for driving licensure and car ownership: A socio-ecological approach. Transp. Policy *36*, 19–25.

Sopjani, L., Stier, J.J., Hesselgren, M., Ritzén, S., 2020. Shared mobility services versus private car: Implications of changes in everyday life. J. Clean. Prod. *259*, 120845.

Storme, T., De Vos, J., De Paepe, L., Witlox, F., 2020. Limitations to the car-substitution effect of MaaS. Findings from a Belgian pilot study. Transp. Res. Part A: Policy Pract. *131*, 196–205.

Verma, S., Dwivedi, G., Verma, P., 2022. Life cycle assessment of electric vehicles in comparison to combustion engine vehicles: a review. Mater. Today.: Proc. 49, 217–222.

Walker, I., & Bösehans, G. (2016). Electric cars won't save our cities. Retrieved January 25, 2023, from ⟨https://www.theguardian.com/sustainable-business/2016/jan/08/Electric-cars-wont-save-our-cities-transport-self-driving-robots⟩.

Wang, C., Zhang, Y., 2023. Inferring and comparing trip purposes of shared micromobility services: a case study of Ningbo, China. Trans. Urban Data, Sci., Technol. 27541231231179884.

Willing, C., Brandt, T., Neumann, D., 2017. Intermodal mobility. Bus. Inf. Syst. Eng. *59* (3), 173–179.

Zhou, Y., Yu, Y., Wang, Y., He, B., Yang, L., 2023. Mode substitution and carbon emission impacts of electric bike sharing systems. Sustain. Cities Soc. *89*, 104312.