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Shared bikes vs. private e-scooters. Understanding patterns of use and demand in a policy-constrained micromobility environment

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ABSTRACT

Urban mobility has undergone a transformation with the advent of micromobility vehicles, leading to a multitude of studies investigating the factors that drive early adoption and the sustainability and equity implications. However, in a context where local administrations struggle regarding how to fit different micromobility systems within the urban ecosystem, little is understood about how political regulations impact micromobility users' modal choices This study aims to shed light on the differences between private e-scooters and shared bikes in Barcelona, a city where micromobility options face distinct regulatory frameworks, and also to understand the factors that influence an individual's choice between these two modes of micromobility. The study employs a self-reported intercept survey on 651 micromobility users and builds a logistic binary regression model to examine the characteristics that differentiate e-scooter and shared bike adopters. Results indicate notable differences between adopters of the two modes and suggest that city regulations might play a role in determining the choice of mode. Furthermore, the study finds that while both modes follow similar mode replacement paths, shared bikes have a higher potential to keep users away from cars. These findings contribute to the limited knowledge on the choice between different modes of micromobility and highlight the impact of policy design on diverse population groups. As more cities are banning free-floating from city centres, it is essential to understand how these selective bans and restrictive policies have an impact on micromobility users' modal choices.

1. Introduction

In recent years, there has been the introduction of a myriad of electric devices and new-shared transportation options offering the promise of a new, cleaner, and more dynamic transportation system, with all of them falling under the vast concept of "micromobility". These new forms of transport have been tolerated, or even promoted, worldwide under the premise that they might help the transition towards a cleaner and more sustainable transportation system, as well as potentially improving transport equity by providing cheap and easy access to basic mobility options. The potential for these new modes of transport to aid climate change efforts or generate more equitable transport systems, however, remains under debate. To better understand the impact of micromobility on current transportation systems it is imperative to conduct comprehensive research and analysis of the various factors involved. Hence, gaining insight into the patterns of use and demand of specific micromobility solution, has become more important than ever. This paper contributes to the discussion by focusing on the case of Barcelona, a city with an effervescent and particular micromobility environment that can serve as a reference point for the challenges that other cities might face in the future.

As cities continue to experience increasing levels of population and congestion, many individuals are seeking out alternative forms of personal transportation. Two of the major exponents of these emergent mobility devices in European urban environments include e-scooters and docked-BSS (bike-sharing systems). While they are often grouped under the same umbrella of alternative transportation, e-scooters and shared bikes have distinct impacts on the overall transportation system. Their differing speeds and rates of acceleration differentiate their behaviour on the streets, forcing the other users to adapt and cope in different ways (Cubells et al., 2023b). Moreover, their distinct physical characteristics require a different transport infrastructure, including varying street surface, street network, and road design (Glavic et al., 2021). Specifically, e-scooters are defined as *scooters with a standing*

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design with a handlebar, deck, and wheels that are propelled by an electric motor (Shaheen and Cohen, 2019), while docked-BSS are defined as those systems that offer *either conventional or electric bicycles to enable short-term rental from one docking station to another* (Fishman et al., 2013).

The major interest in these new modes of transport has resulted in an already significant body of literature examining the determinants of its early adoption, including the sociodemographic characteristics of users, their beliefs and perceptions, and the motivations explaining their modal choice (Ampudia-Renuncio et al., 2018; Becker and Rudolf, 2018; Burghard and Dütschke, 2019; Fishman, 2016; Laa and Leth, 2020; W. Li and Kamargianni, 2018). Surprisingly, however, these studies tend to address micromobility as a homogenic block, or select only one of the multiple modes that fall within the micromobility definition (Fishman et al., 2013; Jiao and Bai, 2020). As a result, there exists a lack of studies addressing the key determinants that may influence the choice of one micromobility mode over another. In other words, little is known about why an individual who is willing to use a micromobility device, ends up choosing a bike over an e-scooter, or vice versa. Understanding these factors is even more important when different modes of transport do not share the same mobility operating system. This is the case in cities where one can find an established bike sharing system, but not an e-scooter sharing system. In these cases, uncovering the factors leading people towards the shared system over the privately-owned system is key in guaranteeing the success of the public alternative. Shedding light on the elements influencing modal choice within micromobility options can also help in understanding the specific role of each micromobility device and its contribution to the overall transport system. This research topic is particularly important when the issue under debate is micromobility's potential to promote fairer and more equitable transport systems.

This paper is aimed at understanding what drives users towards privately-owned e-scooters over shared bikes, and which factors are involved in each specific modal choice. This study uses data from a travel survey conducted in Barcelona, Spain and is based on a four-step analysis: (1) an exploration of the user profile of each of the two most well-known micromobility alternatives in Barcelona; (2) an examination of the most prominent socioeconomic and mobile predictors explaining private e-scooter usage as a modal choice over BSS usage; (3) a description of the origin of the demand of each of the micromobility modes; and (4) an exploration of the subjective evaluation of private e-scooter and BSS users. The remainder of the paper is structured as follows. Section 2 reviews the determinants of micromobility modes, in addition to examining the few urban settings that share similar micromobility frameworks with Barcelona. Section 3 presents the study area, the data collection process, and a description of the methodology used. Section 4 provides the main results, while Section 5 discusses those results, and includes a reflection on the impact of political decisions on the degree of popularisation of different micromobility options. Finally, the conclusions and study limitations can be found in Section 6.

2. Background

2.1. Micromobility adoption: characteristics, impacts, and motivations

Micromobility has already become a trend in the mobility and transportation literature (Abduljabbar et al., 2021; Elmashhara et al., 2022; Fulton, 2018; Mouratidis, 2022). Although it is a young research field, most studies identify a common set of demographic and socioeconomic factors that are shared by different types of micromobility devices. Typically, micromobility users are young, highly-educated males with full-time employment (McKenzie, 2019; Mouratidis, 2022; Reck and Axhausen, 2021; Shaheen and Cohen, 2019). However, despite these common traits, the previous body of literature has acknowledged nuances across distinct devices. In terms of gender, for instance, greater imbalances are commonly found among e-scooter riders (Hosseinzadeh et al., 2021; Jiao and Bai, 2020; Nikiforiadis et al., 2021; Sanders et al., 2020) than among bike-sharing users (Goodman et al., 2014; Mouratidis, 2022; Roig-Costa et al., 2021). Slight differences across devices can also be found regarding socioeconomic characteristics. On the one hand, in the case regarding bike-sharing, a vast majority of the previous literature agrees that users tend to have higher levels of education (Ricci, 2015; Shaheen et al., 2014). However, this clear consensus does not exist regarding e-scooters. In this case, while some studies have found a more prevalent use of e-scooters in neighbourhoods with highly educated people (Bai and Jiao, 2020; Clewlow and Mishra, 2017; Merlin et al., 2021), associations between higher levels of education and a higher degree of riding are not supported by other studies (Mitra and Hess, 2021). Other factors that seem to be associated to micromobility use are ownership of a driving license, or having access to a private car. However, these associations seem to be dependent on the context, as the literature has reached indistinctly perceived conclusions, in the case for bike-sharing (Bielinski and Wazna, 2020; Eren and Uz, 2020) and also in the case for e-scooter usage (Blazanin et al., 2022; Mouratidis, 2022; Reck and Axhausen, 2021).

In contrast, an issue that the literature generally agrees on is the fact that micromobility's introduction impact is highly conditional on the type of vehicle that all these new transport modes are replacing. Multiple studies concur in finding that any reduction in the negative environmental and social externalities that are associated with transport are only truly achieved when the modal change involves replacing automobiles (Felipe-Falgas et al., 2021; Hollingsworth et al., 2019; López-Dóriga et al., 2022; Sheng et al., 2016; Weiss et al., 2015). However, to date, the previous literature on micromobility has generally found that the introduction of both shared bikes and e-scooters primarily replaces active and public transportation, with only a limited impact on car users (Felipe-Falgas et al., 2021; Fishman et al., 2013; Reck et al., 2022; Teixeira et al., 2020; Wang et al., 2022). This is especially true for BSS, as documented by studies that were undertaken across various locations, such as Ireland (Murphy and Usher, 2015), Poland (Bieliński et al., 2021), or Australia (Fishman et al., 2014). While research on the effects of e-scooters is still in its early stages, initial findings by Christoforou et al. (2021a) in Paris (France) and Bai and Jiao (2020) in Austin (Texas, USA) suggest that e-scooters often replace walking, cycling, or public transportation, which is similar to the conclusions reached in bike-sharing studies.

To date, it is also widely accepted that aspects such as ease of use and comfort (Hardt and Bogenberger, 2019; Plazier et al., 2017; Simsekoglu and Klöckner, 2019; Teixeira et al., 2020), accessibility and flexibility (Dill and Rose, 2012; Eccarius and Lu, 2018; Esztergár-Kiss and Lopez Lizarraga, 2021; Popovich et al., 2014), or time saving (Bateman et al., 2021; Glavic et al., 2021; Kaplan et al., 2018; Krauss et al., 2022) are positively associated with general micromobility use, giving these vehicles a competitive advantage over other traditional modes of transport (Bretones and Marquet, 2022). Contrastingly, safety concerns are often the most noted negative factors associated with micromobility vehicles, hence they present a clear barrier to their adoption (Bretones et al., 2023; Fitt and Curl, 2020; Kopplin et al., 2021; Mitra and Hess, 2021; Sellaouti et al., 2019). Beyond these certainties, there are other functional factors whose effect in micromobility's adoption is, to date, not fully clear. Monetary cost, for instance, varies from being a barrier to adoption to a facilitator of it, depending on the nature of the vehicle (Abouelela et al., 2021; Bateman et al., 2021; Eccarius and Lu, 2020; Hyvönen et al., 2016; Rejali et al., 2021). Difficulties in finding vehicles when needed or discovering them to be broken, low carrying capacities, and the heaviness of the vehicles themselves are other examples why sharing systems are often seen as impractical and inconvenient micromobility strategies, compared to private micromobility. This is especially true when the vehicles are being used to commute to work, because the factor of time can be particularly relevant. However, when travelling for personal or leisure purposes, these characteristics do not seem to be determinant (Eccarius and Lu, 2020; Sanders et al., 2020). Reliability is also a factor that seems to differ according to the

micromobility vehicle in question. According to Krauss et al. (2022) and Patil and Majumdar (2021), unlike users of sharing schemes, micromobility vehicle owners often state the risk of theft (especially when parking in public spaces) and the 'range anxiety' (potential insufficient battery charge) as major concerns. In sum, there are a significant number of functional factors whose association with micromobility depends largely on the type of vehicle (scooter vs. bike), and on the type of mobility operating system (shared vs. private).

2.2. E-scooters and BSS in the context of a policy-constrained micromobility environment

Cities, globally, started adopting bike-sharing systems (BSS) around the 2010s, through both public and private initiatives (Chen et al., 2020; Galatoulas et al., 2020; NACTO, 2019). E-scooters were then incorporated, mainly through allowing private initiatives to operate in the city (Brustein, 2018; Marshall, 2018; POLIS, 2019). Because of these chronological differences, both transport managers and policymakers have had to adapt city regulations to the specific needs of each micromobility mode of transport as they were being introduced and becoming more popular. Consequently, regulations for BSS are often not the same as those for e-scooters. Most importantly, the degree of acceptance that cities have had towards publicly operated BSS, has not always been extended to the privately operated scooter-sharing systems (SSS). A number of instances have seen a municipality promote and protect the implementation of BSS, to later oppose or overregulate the deployment of SSS. This is the case for Luxembourg, whose City Council requested free-floating companies to remove e-scooters from the streets in 2019, or Riga, which submitted a proposal to the Latvian parliament to revoke or suspend the license of e-scooter sharing services. More recently, in April 2023, Paris voted to join this group. Through a binding referendum, citizens voted to not extend licenses to operators, and to effectively ban shared e-scooter from public spaces. Beyond European borders, cities as Winston-Salem (North Carolina, US) or Dallas (Texas, US) are just two examples where municipalities have banned the use of SSS due to public safety concerns.

These fragmentations of regulations, for both terms of use and service provision, have relevant implications on how transferrable and replicable results of research conducted in areas with different policy and regulation scenarios are. To date, however, most analyses seem to wrongly assume that the same policies and regulations affect all available micromobility modes equally. In this context, most of the studies have employed datasets of a single micromobility service, and only a few comparative studies of two modes exist (Campbell et al., 2016; Lazarus et al., 2020; Younes et al., 2020). To our knowledge, there is not yet any literature on the usage, competition, and mode choice behaviour between private e-scooters and docked-bike sharing.

The aim of this paper is, therefore, to fill the research gap regarding the lack of understanding on why users prefer private e-scooters over shared bikes, or vice versa. In doing so, this paper also analyses some of the underlying and subjective aspects of micromobility use, such as satisfaction levels or reasons for choosing each individual mode of micromobility. By using the Barcelona case, we are able to locate this analysis in a city with optimal micromobility conditions and two well-established micromobility-operating modes. This enables us to identify the different determinants of modal choice, as well as to assess how likely the users of each mode are to maintain their modal choice in the future. This is particularly important, given the growing prevalence of urban settings, where two of the main micromobility actors differ, not only in the type of vehicle but also, in their operating systems.

3. Methods

3.1. Study setting

Barcelona is a city with a dense, compact, and mixed-used built environment with about 1.6 million inhabitants (IDESCAT, 2020). With a wide-ranging public transport system, consisting of metro lines, trains, trams, and buses that are distributed throughout the municipality, the city seems to offer the ideal scenario for the implementation of both shared bikes and e-scooters (Marquet and Miralles-Guasch, 2014; McKenzie, 2019). The city operates a successful public bike-sharing system since 2007 under the operator known as "Bicing", with more than 100,000 users and a fleet of 7000 vehicles (Soriguera and Jiménez-Meroño, 2020). In 2021, according to the official data, trips using that public docked-bike sharing system grew by 22%, compared to the previous year (Ajuntament de Barcelona, 2021). On the other hand, in 2017 the City Council of Barcelona enacted legislation prohibiting free-floating electric scooter companies (e.g., Lime or Bird) from operating within the city's administrative boundaries (Ajuntament de Barcelona, 2017). Banning shared e-scooter providers from operating within the city-limits was mainly oriented to avoid incidents and dysfunctions that are related to parking malpractice and the occupation of public space. The measure, however, has resulted in a rapid rise in the popularity of privately owned e-scooters, which translated into an increase in e-scooter trips by 179.6% with respect to 2020 (EMEF, 2021). The resulting micromobility scenario is thus one that is also typical of other urban areas, where regulations have made the experience of using and accessing shared e-scooter and bike systems largely different experiences.

3.2. Data gathering

Data collection was performed by eight street interviewers (Supplementary Table 1) with the help of tablets (Computer-Assisted Personal Interviews, CAPI method), during the second half of September 2020. In order to organise the fieldwork and obtain a sample of users circulating in different parts of the city, recruitment was conducted from 14 survey points covering nine out of ten city districts (Supplementary Table 2). Participants were randomly intercepted on the street or at bike-sharing stations, and they were invited to participate, either before they would start a trip, during an ongoing trip, or after finishing their trip on a private e-scooter or on a docked-shared bicycle. In crowded places, no more than one interview was conducted per group (e.g., per family or group of friends). While this is a non-probabilistic sampling method, it is a cost-effective, faster, and easier way to collect data. To ensure the representativeness of our sample, we undertook a validation exercise using alternative data sources, revealing that the demographic characteristics of our sample, including gender and age, align with those of the broader population who are utilising micromobility within the city. In total, 651 surveys were conducted, over a total period of ten days, with private e-scooter and BSS users above 16 years of age (which is the minimum age allowed to ride an e-scooter and/or short-rent a docked-public bike), who are living and/or working in Barcelona. The survey, which included mainly close-ended questions and lasted approximately 10–15 min, provided information about the respondents' sociodemographic profile, current and former travel behaviours, preferences, and motivations (Roig-Costa et al., 2021).

3.3. Statistical analysis

In order to assess the different aspects of micromobility, a four-step analysis was designed to (1) explore the user profile of each of the two most well-known micromobility alternatives in Barcelona; (2) examine the most prominent socioeconomic and mobile predictors explaining private e-scooter usage as a modal choice over BSS usage; (3) inform the origin of the demand of each of the micromobility modes; and (4) explore the subjective evaluation of private e-scooter and BSS users.

Firstly, to provide an initial description of the user profiles, a semi-descriptive analysis was estimated through bivariate associations using chi-squared ($\chi 2$) tests between each micromobility option, and a set of exploratory variables. The complete set of variables included

individual and usage-related factors (Table 1). Individual-related variables were age, gender (*Woman, Man, Non-binary,* or *Prefer not to say*), level of studies (*None, Primary, Secondary,* or *University*), professional status (*Employed, Unemployed, Retired, or Student*), place of residency (*Barcelona* or *Out of Barcelona*), and workplace (*Barcelona* or *Out of Barcelona*). Variables related to the usage were frequency of use (*Daily, Occasionally,* or *Almost Never*) of each of the following means of transport: private e-scooter, BSS, metro, bus, train, and car; and dichotomous variables regarding trip purpose (*Yes* or *No*): commuting, caring, leisure, and accessing public transportation.

Secondly, the analysis of the significant predictors of micromobility modal choice consisted of a multivariate binary logistic regression model, devoted to understanding the choice of private e-scooter over BSS. A binary model was chosen due to the almost non-existent usage relationship between both micromobility modes in Barcelona (see Table 1). The dependent variable in our model was being a user of a private e-scooter (1 = Yes and 0 = No), and the set of explanatory variables was selected after testing for significance in a bivariate Pearson χ^2 test. The independent variables included demographic factors (Age and Gender), socioeconomic factors (Education level and Professional status), territorial factors (Place of residence and Place of work), and self-reported habitual travel attitudes (Frequency of use and Trip purpose).

Thirly, to assess the mode replacement dynamics of the different micromobility users the survey included the following counterfactual question: "*Which mode of transport would you have taken if this one (BSS or E-scooter, according to the respondent) had not existed?*". We used a Sankey diagram (SD), which is a visualization that is used to depict a flow (links) from one set of values to another (nodes). In Fig. 1, the axis on the left side, which indicates the former mode to micromobility, included active modes (*Walking* and *Cycling*), public transport modes (*Subway, Bus* and *Train*), and private modes (*Car* and *Motorcycle*). Respondents were also given the option to answer *"I would have not made this trip"*. The axis on the right side shows the current micromobility mode, either BSS or private e-scooter. The volume of the links between nodes represents the importance of a specific modal replacement combination.

Finally, to assess the subjective evaluation of using different micromobility modes in Barcelona, we used descriptive statistics to compare both the level of satisfaction of individuals with their current micromobility mode, and the change in satisfaction level with respect to their former mode of transport. In a similar manner to that used by (Paviotti and Vogiatzis, 2012), satisfaction with their current micromobility mode was ranked on a scale from 0 to 10, and change in satisfaction level was measured on a scale from *Less satisfactory* to *More satisfactory*. Next, the stated reasons for using either a private e-scooter or BSS were compared. Participants could state up to 3 different reasons in a close-ended question. This type of data has already been used in other transport studies to compare public transport and car users (Van Exel and Rietveld, 2009), or to describe motorcycle behaviour (Marquet and Miralles-Guasch, 2016). To the best of our knowledge, this is the first time that this type of data has been used to describe micromobility behaviour. Analyses were conducted using IBM SPSS v21.

Table 1
Individual and usage-related characteristics of the sample.

		E-scooter users		BSS users	
		N	%	N	%
Individual-related factors					
Gender	Woman	117	36.1*	148	45.8**
	Man	207	63.9**	175	54.2*
Age	<30 yrs	159	48.8	162	49.8
	30–49 yrs	142	43.6	126	38.8
	>50 yrs	25	7.6	37	11.4
Professional status	Employed	255	78.2**	216	66.5*
	Unemployed	19	5.8	17	5.2
	Retired	8	2.5	5	1.5
	Student	44	13.5*	87	26.8**
Level of education	None or primary	31	9.5	22	6.8
	Secondary	160	49.1**	109	33.5*
	University	135	41.4*	194	59.7**
Place of residency	Barcelona	257	78.8*	309	95.1**
	Out of Barcelona	69	21.2**	16	4.9*
Workplace	Barcelona	244	74.8**	182	56.0*
	Out of Barcelona	82	25.2*	143	44.0**
Usage-related factors					
Use of private e-scooter	Daily	277	85.0**	8	1.2*
	Occasionally	46	14.1**	16	3.7*
	Almost never	3	0.9*	309	95.1**
Use of BSS	Daily	9	2.8*	229	70.9**
	Occasionally	15	4.6*	79	24.5*
	Almost never	302	92.6**	15	4.6*
Use of metro	Daily	43	13.2*	80	24.6**
	Occasionally	91	27.9*	139	42.8**
	Almost never	192	58.9**	106	32.6*
Use of bus	Daily	20	6.1*	42	13.0**
	Occasionally	63	19.3*	99	30.6**
	Almost never	243	74.6**	183	56.4*
Use of train	Daily	24	7.3**	12	3.7*
	Occasionally	24	7.4*	55	16.9**
	Almost never	278	85.3**	258	79.4*
Use of car	Daily	25	7.7	21	6.5
	Occasionally	66	20.2**	42	12.9*
	Almost never	235	72.1*	262	80.6**
Purpose: Commuting	Yes	203	62.3**	155	47.7*
	No	123	37.7*	170	52.3**
Purpose: Caring	Yes	81	24.8	90	27.7
	No	245	75.2	235	72.3
Purpose: Leisure	Yes	80	24.5	99	30.5
	No	246	75.5	226	69.5
Purpose: Accessing PT	Yes	18	5.5	19	5.8
	No	308	94.5	306	94.2

* = indicates significantly lower values than the overall distribution of the micromobility sample average.
** = indicates significantly higher values than the overall distribution of the micromobility sample average.

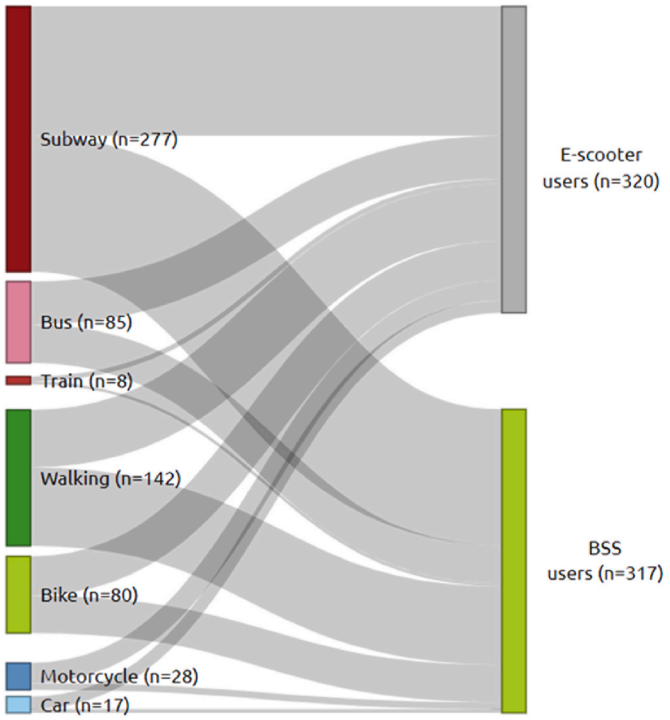

Fig. 1. E-scooter and BSS modal replacement scheme.

4. Results

4.1. Exploring micromobility profiles and use: a bivariate analysis

Given the rapid proliferation of micromobility devices in Barcelona, it is important to understand the profile of the user. Men represent almost six out of ten users (59.0%), with the gender imbalance being particularly high for private e-scooter users (63.9% are men). In terms of age group, almost half of the respondents are under 30 years of age (49.3%). Although no significant differences are found between modalities, those respondents over 50 years of age are more likely to be BSS users than private e-scooter users (11.4% compared to 7.7%, respectively). Regarding professional status, the vast majority of respondents are employed (e-scooter 78.2%; BSS 66.5%). However, significant differences are found in the proportion of students using BSS (26.8%) and e-scooters (13.5%). There are also important contrasts with respect to educational level: while 41.4% of e-scooter users have completed their university studies, this percentage rises to 59.7% in the case of BSS users. Finally, significant differences are found in the place of residence and in the place of work. While 78.8% of e-scooter users live within the administrative limits of the city compared to 95.1% in the case of BSS users, 74.8% of e-scooter owners declare working in the city compared to only 56.0% of BSS users.

The rapid introduction of micromobility in cities also requires an understanding of the usage of these new modes of transport. The second part of Table 1 shows the frequency of use of micromobility and traditional modes, together with micromobility trip purposes. Specifically with regard to the frequency of use of micromobility modes, private e-scooter users report a much higher daily use of e-scooter than BSS users report using bike-sharing on a daily basis (85.0% vs. 70.9%, respectively). However, the most noteworthy result is that fact that the vast majority of e-scooter and BSS users state that they never use the other micromobility alternative (95.1% of e-scooter declared never using BSS, while 92.6% of BSS users declared never riding a private e-scooter). Regarding frequency of use of other modes of transport, differences are particularly significant with respect to metro and bus uses, where BSS users show much higher percentages of daily and occasional use than private e-scooter users. Despite some significant differences being found in car use frequency between e-scooter owners and BSS users, those differences are lower. Finally, in terms of trip purposes, the difference between private e-scooter and BSS users with respect to commuting stands out significantly (while 62.3% of the e-scooter respondents cited commuting as a purpose, only 47.7% of BSS users stated the same). Surprisingly, only around 5.5% of users declared using micromobility with the intention of accessing public transportation, with no significant differences between different modes.

4.2. Explaining micromobility as a modal choice: a multivariate analysis

In aiming at understanding which factors are behind this growth in micromobility, it is necessary to identify the demographic and usage-related factors that explain the decision to use a private e-scooter. The binary logit model in Table 2 takes into account selected socioeconomic and usage variables, in order to determine the main factors of e-scooter use over docked short-rental bicycle. Results suggest that private e-scooter use is identified with younger men and that it declines with age. The probability of using a private e-scooter is also greater among those respondents who use micromobility for commuting purposes, especially if their place of work falls within the Barcelona City boundaries. On the other hand, results of the regression analysis suggest that the probability of using BSS is greater among those respondents with a university degree. Being a student, living within Barcelona City boundaries, and relying on micromobility for leisure purposes is also associated with a greater probability of using BSS versus using a private e-scooter. In addition, using the metro occasionally or on a daily basis, and the train in an occasional manner, is also associated with a higher probability of using BSS as a micromobility mode over a private e-scooter.

4.3. Mode replacement dynamics of micromobility

A particularly relevant issue for the study of micromobility in cities is the modal origin of new users. In order to understand where the micromobility demand comes from, Fig. 1 shows the mode of transportation which both private e-scooter users and BSS users used prior to using their micromobility device. On average, 56.8% of the current micromobility users switched from public modes of transport and 34.1% switched from active modes of transport, whereas only 6.91% switched from a private mode of transport.

By type of vehicle, the largest mode transfers are found between the metro and BSS (43.7%), and between the metro and private e-scooter (41.4%). Walking is the second highest mode of transport to have been abandoned in favour of either BSS (25.2%) or private e-scooter (18.6%). Regarding private motorised modes of transportation, there is a slight difference between private e-scooter users and BSS users: while more

Table 2
Binary logit model of the probability of using a private e-scooter over using BSS in Barcelona.

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
Variables								Inferior	Superior
Constant		2.586	0.534	23.478	1	0	13.276		
Age		−0.035	0.01	11.924	1	0	0.966	0.947	0.985
Gender	Woman	−0.66	0.195	11.479	1	0.001	0.517	0.353	0.757
Professional status	Employed			27.727	3	0			
	Unemployed	0.956	0.49	3.806	1	0.051	2.602	0.996	6.801
	Retired	1.178	0.723	2.651	1	0.103	3.248	0.787	13.408
	Student	−1.242	0.38	10.697	1	0.001	0.289	0.137	0.608
Education	None or primary			29.9	2	0			
	Secondary	0.196	0.361	0.296	1	0.587	1.217	0.599	2.471
	University	−0.993	0.372	7.136	1	0.008	0.37	0.179	0.768
Place of residency	Barcelona	−1.991	0.368	29.254	1	0	7.32	3.558	15.057
Workplace	Barcelona	0.963	0.303	10.114	1	0.001	0.382	0.211	0.691
Trip purpose	Commuting	0.592	0.208	8.107	1	0.004	1.808	1.203	2.718
Trip purpose	Leisure	−0.549	0.222	6.097	1	0.014	0.577	0.373	0.893
Use of metro	Never			30.729	2	0			
	Sometimes	−0.993	0.208	22.865	1	0	0.37	0.247	0.557
	Often	−1.201	0.278	18.683	1	0	0.301	0.174	0.519
Use of train	Never			8.544	2	0.014			
	Sometimes	−0.957	0.329	8.441	1	0.004	0.384	0.201	0.732
	Often	−0.054	0.454	0.014	1	0.906	0.948	0.389	2.307

Notes for the model: Rho-Square (Nagelkerke) = 0.353; -2log likelihood = 696.782; Pseudo R^2 (Cox and Snell) = 0.265.

than 10% of private e-scooter owners come from private motorised modes, only 3.4% of BSS users were previously driving a private motorised vehicle.

4.4. Subjective evaluation of micromobility

Table 3 shows, on a scale from one to ten, how owners of e-scooters and users of BSS evaluate their satisfaction with their micromobility mode. Private e-scooter users evaluate their mode of transport the highest, the average mark being X = 8.94, in comparison with X = 7.51 of BSS users. On average, e-scooter users are 1.19 times more satisfied than BSS users. By transport mode, former public transport users show the highest differences (1.22) between e-scooter and BSS. Only among users switching from private modes, do e-scooter users show a lower average level of satisfaction than their BSS counterparts. In fact, across all current e-scooter users, former users of private modes show the lowest satisfaction mark. At the same time, those respondents showing the highest satisfaction level across all BSS users are precisely the ones switching from private modes.

In addition, the satisfaction levels of private e-scooter users and BSS users transitioning to micromobility were assessed using a scale ranging from *Less satisfactory* to *More satisfactory* (Fig. 2). Results reveal an overall positive trend in micromobility user satisfaction. However, a substantial difference arises between those respondents coming from active and public modes of transport, and other respondents coming from private motorised modes. While almost no former public transport users report feeling less satisfied with the new micromobility mode of transport, a considerable percentage of former motorised vehicle users report being less satisfied with the change to micromobility, especially across e-scooter users. Former active modes users appear to be more satisfied with their new mode of transportation. Nevertheless, although the percentage of more satisfied users is significant, the share of former active modes users declaring being equally or less satisfied with the change to micromobility is not insignificant.

To understand why e-scooter users are more satisfied than BSS users, it is important to analyse the reasons behind their choosing to use the e-scooter. Comparing answers from e-scooter owners with those of BSS users also helps to understand the hidden rationale behind each mode of transport choice. As shown in Table 4, in general, both e-scooter owners and BSS users point to similar principal reasons when asked about the main reasons for using micromobility. Of all the BSS users, 60.3% pointed to *"Ease, speed, and agility"* as the main reason, 17.2% to *"Save money"*, and 14.2% to *"Good for the environment"*. E-scooter owners agreed in both the ease of use and speed issue (62.6%), and also with respect to the monetary cost (18.7%), but the environment (6.1%) was clearly not a factor for them.

However, in using a cross-mode strategy for analysis, it is when crossing the current micromobility mode with the replaced transport mode when main reasons for micromobility adoption between e-scooter owners and BSS users diverge significantly. Among former users of private modes, current private e-scooter users are 3.82 times more likely to justify their use of the e-scooter by the ease, speed, and agility that it provides than their BSS counterparts. Former public and active modes users currently using a private e-scooter were 3.1 and 2.66 times, respectively, more likely to rationalise their choice due to personal pleasure (i.e., *"having fun"*). The COVID-19 pandemic was also an important factor for e-scooter owners compared to BSS users, especially for former active and public mode users. In contrast, among current BSS users *"Saving money"* and *"Good for the environment"*, respectively, were cited more by former users of private modes and former active and public mode of transport users. In sum, private e-scooter use is basically characterised by an operational factor such as ease of use, speed, and agility, especially in the case of former private modes users, and by an extra subjective factor, such as personal pleasure, for former active and public modes users.

Table 3
Subjective assessment of satisfaction on private e-scooters and BSS.

Former means of transport	E-scooter users (out of 10)	BSS users (out of 10)	Difference E-scooter/ BSS
All modes	8.94	7.51	1.19
Active modes	8.88	7.53	1.18
Public modes	9.06	7.44	1.22
Private modes	8.51	8.73	0.97

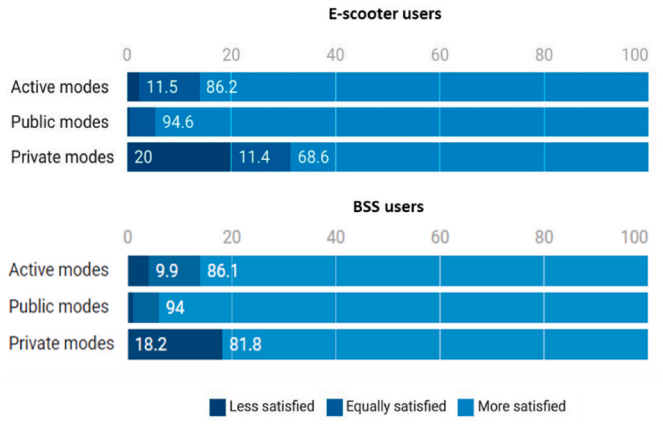

Fig. 2. Change in satisfaction versus former mode of transport.

5. Discussion

The unprecedented boom in micromobility devices on the streets of Barcelona has political, technical, and contextual explanations. On the one hand, the Barcelona City Council's decision in 2007 to promote a short-term bicycle rental system, created the possibility for many non-bicycle owners to use a bicycle for intra-city short-distance travelling. The introduction of an electrified fleet, later allowed for the expansion of the system to parts of the city that were traditionally considered unsuitable for bicycle use, thus reinforcing its popularity (Codina et al., 2022). With respect to e-scooters, the 2017 City Council decree to not allow private operators of shared e-scooters within the city limits completely conditioned the landscape of the sharing services operating within the city and left an unmet demand that swiftly led to the proliferation of privately owned e-scooters. Other contextual factors, such as the COVID-19 pandemic, accelerated micromobility's deployment, leading to an increase of transfers from traditional modes of transport (mainly public transport) towards modes such as BSS or private e-scooter. These modes were perceived as safer alternatives, capturing first-time users who have most likely consolidated their use over time (Li et al., 2021).

In absolute terms, our results confirm that micromobility vehicles in Barcelona are predominantly used by young, urban, and employed men. The masculinisation in the use of micromobility vehicles is a phenomenon that is common to many other cities, such as New York (United States) (Reilly et al., 2020), Gdansk (Poland) (Bielinski and Wazna, 2020), and Passo Fundo (Brazil) (Sardi et al., 2019). A plausible explanation for this gender gap is that women might be more risk averse and sensitive to safety issues (Sanders et al., 2020). In cities like Barcelona, where the bike lane network is still highly fragmented, the feeling of insecurity, compared to other modes of transport, is compounded for women. Our models demonstrate that this relationship between women and risk is especially accentuated in the case of private e-scooters. According to both Arellano et al. (2019) and (Cubells et al., 2023a), e-scooter users who are men drive faster than their women counterparts, with this difference being particularly pronounced in pedestrian areas. In fact, a recent study set in Barcelona found that risk-taking and

Table 4
Reasons for changing to private e-scooter and BSS, according to former transport mode.

	E-scooter users			BSS users			Odds Ratio (E-scooter)		
	Active modes	Public modes	Private modes	Active modes	Public modes	Private modes	Active modes	Public modes	Private modes
Save money	15.9%	21.6%	8.6%	16.8%	20.0%	18.2%	0.93	1.1	0.42
Ease, speed, and agility	70.5%	57.3%	68.6%	68.3%	55.1%	36.4%	1.11	1.09	3.82
Good for the environment	4.5%	6.5%	11.4%	10.9%	15.1%	18.2%	0.39	0.39	0.58
Personal pleasure	4.5%	4.9%	5.7%	2.0%	1.6%	9.1%	2.36	3.1	0.61
COVID-19	3.4%	9.7%	5.7%	2.0%	6.5%	9.1%	1.75	1.55	0.61
Physical activity	1.1%	0.0%	0.0%	0.0%	1.6%	9.1%	-	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			

fast-riding practices can discourage other potential users from sharing the same infrastructure, thus hindering the potential uptake of micromobility modes, and also damaging the prospects for more sustainable mobility (Cubells et al., 2023a). Considering that in Barcelona the majority of pedestrians are women (Maciejewska et al., 2019; Marquet and Miralles-Guasch, 2015), and the majority of e-scooter users are men, the adoption of electrified micromobility may be changing the use and perception of safety in public space, and challenging established patterns in its use, thus creating conflicts that especially affect the most vulnerable social groups (Fitt and Curl, 2020).

Our results also demonstrate the existence of a true generational gap in the use of micromobility vehicles. Due to issues that are linked to health and physical conditions, such as posture problems or loss of balance (Johnson and Rose, 2015), older adults have been found to have a greater aversion to the adoption of micromobility vehicles, and a lower predisposition to the use of technologies that are associated with them (Campisi et al., 2020). The existence of such a pronounced gap calls into question issues about the actual accessibility of these vehicles, and their potential to contribute to transportation justice, especially in the case of the e-scooter (Bielinski and Wazna, 2020; Spinney, 2020).

However, whereas sociodemographic factors, such as gender and age, can explain the growing trend of micromobility as a whole, our results indicate that the decision to actually use private e-scooters over BSS in Barcelona appears to depend more on socioeconomic factors. In contrast to the previous literature, Barcelona shows a strong negative relationship between e-scooter use and educational level, which might be explained in part by the existing ban on shared e-scooters. Unlike in other cities, the use of e-scooters in Barcelona is not subject to owning a smartphone, downloading an app, or paying through a credit/debit card. The user does not require a specific knowledge on vehicle location and how to unlock the vehicle, or any expertise regarding parking prohibition and regulation. Notably, unlike the prevailing trend observed in most Western cities, e-scooter usage is not contingent upon a pay-per-use model, a factor which is commonly found to act as access barriers for low-income groups. The political decision to ban free-floating e-scooters left an unmet demand that swiftly sought comfort in private e-scooters. This sudden demand for privately owned e-scooters drove down their selling prices, making it an inexpensive personal mobility alternative that requires only a modest initial investment (around 200 euro), what has led to an even faster proliferation of privately owned e-scooters. The removal of the technological, economic, and information barriers has especially accelerated the introduction of the private e-scooter among socioeconomically disadvantaged populations, offering the dynamism and convenience of micromobility services, without having to participate in electronic payments, app registrations, or formal registration.

This dynamic might be even stronger, given the fact that other shared micromobility services such as public BSS or shared mopeds, that are indeed allowed to effectively operate in the city, have spatial biases and offer unequal service to all city areas (Bach et al., 2023). In practice, what this means is that these services are often limited to operate within the municipal limits, and are specifically concentrated in central areas, where people with higher socio-economic status tend to live, resulting in a lower supply in lower income neighbourhoods. These service-coverage issues have been found in other European cities (Dill et al., 2019), but in the case of Barcelona they contribute to explain the popularity of private e-scooters, which allow for crossing municipal boundaries, metropolitan multimodality and better convenience on planning complex routes. The combination of banning shared e-scooter services to operate within city boundaries, and the fact that other micromobility shared services concentrate their services in central areas of the city, might have led a substantial number of low-income people in the city to adopt privately owned e-scooters, now seen as a highly convenient everyday mobility alternative.

At the same time, our model confirms that micromobility use in Barcelona is strongly linked with trip purpose. On the one side, e-scooter use in our study appears to be strongly associated with occupational mobility. This finding contradicts previous studies on the subject (Bai et al., 2021; Li et al., 2022), where e-scooter trip purposes are more likely to relate to leisure and recreation activities. In contrast, our results show that BSS use is more associated with leisure trips. These differences across distinct operating systems might be related with time management issues. For work-related trips, the variability and uncertainty in travelling can create anxiety around the fear of being late (Costa et al., 1988; Delclòs-Alió and Miralles-Guasch, 2017). Since in some parts of the city the demand for shared bikes tends to be higher than the supply, users do not have the total certainty of being able to access a vehicle when needed, making travel time unpredictable. This would explain why a large proportion of BSS users rely on other modes of transport for their commute to work. The private nature of the e-scooter eliminates the uncertainty that is derived from the possible lack of supply (De Witte et al., 2013), which would explain its greater use for work purposes. This is reinforced by topography, the Mediterranean climate (i.e., sub-tropical coastal), and the degree of physical effort that is required during commuting, connected with the fact that most workplaces in the city lack shower facilities, dryers, or lockers. This combination seems to discourage the use of BSS in work-related trips, and increases the use of private e-scooters, which require less effort (Hipp et al., 2017; Zhu et al., 2020). In contrast, for trips that are related to personal reasons, which tend to be associated with greater spatial complexity, carrying around a private e-scooter can be seen as a burden (Scheiner and Holz-Rau, 2017). In addition, mobility for personal purposes is often associated with a greater use of proximity (Marquet and Miralles-Guasch, 2014), thus allowing for more relaxed time management, which is reflected in a greater use of BSS.

On a replacement analysis level, our results indicate that in Barcelona most of the new users of micromobility are former users of public and active modes of transport. These findings are consistent with the previous literature (Bieliński et al., 2021; Murphy and Usher, 2015; Teixeira et al., 2020) and contrast with the belief that micromobility emergence can help us decarbonise mobility and lower car-dependency in urban areas (Feng et al., 2020; Hardt and Bogenberger, 2019; The Nunatak Group, 2019). This is especially true in European urban environments (Wang et al., 2022), where cars represent lower percentages in

the modal split due to historical built environment conditions. From an environmental perspective, our findings suggest that although micromobility adoption might bring a slight reduction in traffic congestion, air and noise pollution, and energy consumption (DeMaio, 2009; Shaheen et al., 2011), to date, that potential is low (Felipe-Falgas et al., 2021). On the other hand, this modal shift also has implications in terms of health, especially in relation to the use of electric modes of transport (Milakis et al., 2020). Although it is premature to state what consequences it may have (Ognissanto et al., 2018), it does appear that e-scooter use decreases physical activity more than bike sharing. At the same time, in terms of the occupation of public space, the increase in the number of micromobility users places even more pressure on the limited resource of public space, especially in a context of a compact and highly dense city such as Barcelona.

Linked with the above, but focusing on the subjective dimension of the analysis, it is noteworthy how former users of public transport modes are much more satisfied with the change to micromobility than former private transport modes users. According to De Vos and Witlox (2017), the choice of a travel mode will probably be affected by satisfaction with previous trips using that particular mode. This link between satisfaction and behaviour also seems to be confirmed by studies in the domain of marketing and customer behaviour (Olsen, 2007). These studies indicate that customer satisfaction strengthens customer loyalty, meaning that satisfied customers are more likely to continue using that service. Considering these theories, it is worrying that the most satisfied users are those replacing public transport modes rather than private transport modes, especially in the case of the private e-scooter. In addition, our results show a strong inverse relationship between the use of metro and train and the probability of using a private e-scooter, suggesting a clear disconnection of e-scooter users from public transport modes, unlike users of BSS, who show wider modal mixes. This phenomenon is especially worrisome considering the traditional importance of public transport as the backbone of metropolitan everyday mobility, and it will have consequences for public space occupation and availability.

The fact that the drivers of micromobility adoption are so differentiated from the drivers of traditional modes, shows that micromobility use cannot be compared or analysed using the same standards as other modes of transport. In addition, nuances between e-scooters and BSS also exist, especially when they do not share the same operating system, and thus proper attention should be given to each of them as a unique form of transport, answering singular and specific user needs. Differences in factors for the adoption of the e-scooter and BSS are even more relevant when considering the modal switch and former modes of transport. For instance, former car drivers who have now become private e-scooter users tend to place more emphasis on ease of use and agility. On the other hand, for users switching from public modes of transport, private e-scooters are more attractive than BSS due to subjective factors such as enjoyment and thrill seeking. Driving in a dense and compact city such as Barcelona seems to provide a playful trip experience for e-scooter riders who are switching from these specific transport modes, in contrast with the more functional trip experience that BSS appear to provide (Christoforou et al., 2021b; Glenn et al., 2020).

6. Conclusions

Our study has analysed fundamental differences that could explain the preferred adoption of privately-owned e-scooters over public BSS in Barcelona. The study has hypothesised that policy restrictions that are present in Barcelona might explain some of the internal differences, especially at the socioeconomic level. We argue that the policy of banning free-floating e-scooter services has resulted in a greater part of the lower-income population choosing to own e-scooters. Paradoxically, a decision that was intended to promote a more democratic and accessible public space, has skewed the relative cost-benefit analysis of different micromobility transport options, and has led to an increase in the desirability of privately-owned e-scooters, particularly among individuals from economically disadvantaged backgrounds. Our results have also shown that micromobility in Barcelona presents features that are similar to those in other urban settings, as young and employed men, on average, use micromobility modes of transport the most. Place of residency, place of work, trip purpose, and frequency of use of public transport, all also have a strong bearing on the likelihood of an individual choosing to use a private e-scooter over the BSS. Barcelona's present circumstances, which were once considered atypical, are gradually becoming commonplace in numerous capital cities across the globe. Hence, we argue that the findings of this study possess a representative nature and merit particular attention within urban contexts that are characterised by comparable legal frameworks, both at the present time and in the foreseeable future.

A worrisome finding is that micromobility modes in Barcelona are not absorbing car users, but rather public transport and former users of active modes of transport, such as walking. This phenomenon calls into question the potential of micromobility as a tool to fight the climate emergency, and it also has implications in terms of health and public space. Finally, our study found that satisfaction indexes differ across replaced modes. These results might mean that the few former private transport users which micromobility has managed to attract might not be as loyal as transport users coming from active and public modes, which would further question the potential of micromobility as a tool with which to combat the hegemony of private motorised vehicles.

This study is not without limitations. Firstly, the utilisation of a non-probabilistic sampling technique, followed by a random intercept mechanism, limits our study's ability to extrapolate our findings to the entire City of Barcelona. In addition, the present authors are aware that, due to the fact that data collection took place when the global traffic situation was of a particularly special nature during the Covid-19 pandemic, results should be viewed carefully. However, although it is true that Barcelona, like many other cities in Europe, implemented specific measures towards the promotion of micromobility (e.g., pop-up bike lanes) to counterbalance the avoidance of transit use, it is also true that most of those interventions have been maintained over time and have even gone further, which may alleviate the limitation.

In conclusion, these findings highlight the fact that micromobility modes rarely operate under a homogenic regulative structure and policy framework in any city. Therefore, it is crucial to understand how specific policy decisions may affect the adoption of e-scooters or shared bikes differently. Policymakers must take into account the socioeconomic consequences of micromobility policies, as well as their effectiveness in addressing the climate emergency, reducing car dependency, and their impact on public space utilisation.

Credit author statement

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Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2023.11.010.

References

Abduljabbar, R.L., Liyanage, S., Dia, H., 2021. The role of micro-mobility in shaping sustainable cities: a systematic literature review. Transport. Res. Part D 92, 102734. https://doi.org/10.1016/j.trd.2021.102734.

Abouelela, M., Al Haddad, C., Antoniou, C., 2021. Are young users willing to shift from carsharing to scooter–sharing? Transport. Res. Part Transp. Environ. 95, 102821 https://doi.org/10.1016/j.trd.2021.102821.

Ampudia-Renuncio, M., Guirao, B., Molina-Sanchez, R., 2018. The impact of free-floating carsharing on sustainable cities: analysis of first experiences in Madrid with the university campus. Sustain. Cities Soc. 43, 462–475. https://doi.org/10.1016/j.scs.2018.09.019.

Arellano, J.F., Frank,), Fang, K., 2019. Sunday drivers, or too fast and too furious? Transp. Find. https://doi.org/10.32866/001c.11210.

Bach, X., Marquet, O., Miralles-Guasch, C., 2023. Assessing social and spatial access equity in regulatory frameworks for moped-style scooter sharing services. Transport Pol. 132, 154–162. https://doi.org/10.1016/j.tranpol.2023.01.002.

Bai, S., Jiao, J., 2020. Dockless E-scooter usage patterns and urban built Environments: a comparison study of Austin, TX, and Minneapolis, MN. Travel Behav. Soc. 20, 264–272. https://doi.org/10.1016/j.tbs.2020.04.005.

Bai, S., Jiao, J., Chen, Y., Guo, J., 2021. The relationship between E-scooter travels and daily leisure activities in Austin, Texas. Transport. Res. Part Transp. Environ. 95, 102844 https://doi.org/10.1016/j.trd.2021.102844.

Bateman, L.B., Fouad, M.N., Sullivan, A., Heider, L., Oates, G.R., 2021. Barriers and facilitators to bikeshare programs: a qualitative study in an urban environment. J. Transport Health 21, 101062. https://doi.org/10.1016/j.jth.2021.101062.

Becker, S., Rudolf, C., 2018. Exploring the potential of free cargo-bikesharing for sustainable mobility. Gaia 27, 156–164. https://doi.org/10.14512/gaia.27.1.11.

Bieliński, T., Kwapisz, A., Ważna, A., 2021. Electric bike-sharing services mode substitution for driving, public transit, and cycling. Transport. Res. Part Transp. Environ. 96 https://doi.org/10.1016/j.trd.2021.102883.

Bielinski, T., Wazna, A., 2020. Electric scooter sharing and bike sharing user behaviour and characteristics. Sustainability 12, 1–13.

Blazanin, G., Mondal, A., Asmussen, K.E., Bhat, C.R., 2022. E-scooter sharing and bikesharing systems: an individual-level analysis of factors affecting first-use and use frequency. Transport. Res. C Emerg. Technol. 135, 103515 https://doi.org/10.1016/j.trc.2021.103515.

Bretones, A., Marquet, O., 2022. Sociopsychological factors associated with the adoption and usage of electric micromobility. A literature review. Transport Pol., 130836 https://doi.org/10.1016/j.tranpol.2022.09.008.

Bretones, A., Marquet, O., Daher, C., Hidalgo, L., Nieuwenhuijsen, M., Miralles-Guasch, C., Mueller, N., 2023. Public health-led insights on electric micro-mobility adoption and use: a scoping review. J. Urban Health. https://doi.org/10.1007/s11524-023-00731-0.

Brustein, J., 2018. Are electric scooters the future of urban transport? Bloomberg. URL. https://www.bloombergquint.com/technology/are-electric-scooters-the-future-of-urban-transport-quicktake.

Burghard, U., Dütschke, E., 2019. Who wants shared mobility? Lessons from early adopters and mainstream drivers on electric carsharing in Germany. Transport. Res. Part Transp. Environ. 71, 96–109. https://doi.org/10.1016/j.trd.2018.11.011.

Campbell, A.A., Cherry, C.R., Ryerson, M.S., Yang, X., 2016. Factors influencing the choice of shared bicycles and shared electric bikes in Beijing. Transport. Res. C Emerg. Technol. 67, 399–414. https://doi.org/10.1016/j.trc.2016.03.004.

Campisi, T., Akgün, N., Ticali, D., Tesoriere, G., 2020. Exploring public opinion on personal mobility vehicle use: a case study in Palermo. Italy. Sustain. Switz. 12 https://doi.org/10.3390/su12135460.

Chen, Z., van Lierop, D., Ettema, D., 2020. Exploring dockless bikeshare usage: a case study of beijing, China. Sustain. Switz. 12 https://doi.org/10.3390/su12031238.

Christoforou, Z., Gioldasis, C., de Bortoli, A., Seidowsky, R., 2021a. Who is using e-scooters and how? Evidence from Paris. Transport. Res. Part Transp. Environ. 92, 102708 https://doi.org/10.1016/j.trd.2021.102708.

Christoforou, Z., Gioldasis, C., de Bortoli, A., Seidowsky, R., 2021b. Who is using e-scooters and how? Evidence from Paris. Transport. Res. Part Transp. Environ. 92 https://doi.org/10.1016/j.trd.2021.102708.

Clewlow, R., Mishra, G., 2017. Disruptive Transportation: the Adoption, Utilization, and Impacts of Ride-Hailing in the United States, Institute of Transportation Studies. https://doi.org/10.1139/gen-44-3-401.

Codina, O., Maciejewska, M., Nadal, J., Marquet, O., 2022. Built environment bikeability as a predictor of cycling frequency: lessons from Barcelona. Transp. Res. Interdiscip. Perspect. 16, 100725.

Costa, G., Pickup, L., Di Martino, V., 1988. Commuting - a further stress factor for working people: evidence from the European Community - I. A review. Int. Arch. Occup. Environ. Health 60, 371–376. https://doi.org/10.1007/BF00405673.

Cubells, J., Miralles-Guasch, C., Marquet, O., 2023a. Gendered travel behaviour in micromobility? Travel speed and route choice through the lens of intersecting identities. J. Transport Geogr. 106 https://doi.org/10.1016/j.jtrangeo.2022.103502.

Cubells, J., Miralles-Guasch, C., Marquet, O., 2023b. E-scooter and bike-share route choice and detours: modelling the influence of built environment and sociodemographic factors. J. Transport Geogr. 111, 103664 https://doi.org/10.1016/j.jtrangeo.2023.103664.

De Vos, J., Witlox, F., 2017. Travel satisfaction revisited. On the pivotal role of travel satisfaction in conceptualising a travel behaviour process. Transport. Res. Part Policy Pract. 106, 364–373. https://doi.org/10.1016/j.tra.2017.10.009.

De Witte, A., Hollevoet, J., Dobruszkes, F., Hubert, M., Macharis, C., 2013. Linking modal choice to motility: a comprehensive review. Transport. Res. Part Policy Pract. 49, 329–341. https://doi.org/10.1016/j.tra.2013.01.009.

Delclòs-Alió, X., Miralles-Guasch, C., 2017. Suburban travelers pressed for time : exploring the temporal implications of metropolitan commuting in Barcelona. J. Transport Geogr. 65, 165–174. https://doi.org/10.1016/j.jtrangeo.2017.10.016.

DeMaio, P., 2009. Bike-sharing: history, impacts, models of provision, and future. J. Public Transp. 12, 41–56. https://doi.org/10.5038/2375-0901.12.4.3.

Dill, J., McNeil, N., Howland, S., 2019. Effects of peer-to-peer carsharing on vehicle owners' travel behavior. Transport. Res. C Emerg. Technol. 101, 70–78. https://doi.org/10.1016/j.trc.2019.02.007.

Dill, J., Rose, G., 2012. Electric bikes and transportation policy. Transport. Res. Rec. 1–6 https://doi.org/10.3141/2314-01.

Eccarius, T., Lu, C.C., 2020. Adoption intentions for micro-mobility – insights from electric scooter sharing in Taiwan. Transport. Res. Part D 84, 16. https://doi.org/10.1016/j.trd.2020.102327.

Eccarius, T., Lu, C.-C., 2018. Exploring consumer reasoning in usage intention for electric scooter sharing. Transp. Plan. J. 47, 271–295. https://doi.org/10.6402/TPJ.

Elmashhara, M.G., Silva, J., Sá, E., Carvalho, A., Rezazadeh, A., 2022. Factors influencing user behaviour in micromobility sharing systems: a systematic literature review and research directions. Travel Behav. Soc. 27, 1–25. https://doi.org/10.1016/j.tbs.2021.10.001.

EMEF, 2021. Enquesta de Mobilitat en Dia Feiner 2021.

Eren, E., Uz, V.E., 2020. A review on bike-sharing: the factors affecting bike-sharing demand. Sustain. Cities Soc. 54 https://doi.org/10.1016/j.scs.2019.101882.

Esztergár-Kiss, D., Lopez Lizarraga, J.C., 2021. Exploring user requirements and service features of e-micromobility in five European cities. Case Stud. Transp. Policy 9, 1531–1541. https://doi.org/10.1016/j.cstp.2021.08.003.

Felipe-Falgas, P., Madrid, C., Marquet, O., 2021. Assessing Micromobility Environmental Performance Using LCA and Self-Reported Modal Change. The Case of Shared E-Bikes, E-Scooters, and E-Mopeds in Barcelona. Sustain. Switz. Forthcoming.

Feng, C., Jiao, J., Wang, H., Feng, C., 2020. Estimating E-scooter traffic flow using big data to support planning for micromobility. J. Urban Technol. 0, 1–19. https://doi.org/10.1080/10630732.2020.1843384.

Fishman, E., 2016. Bikeshare: a review of recent literature. Transport Rev. 36, 92–113. https://doi.org/10.1080/01441647.2015.1033036.

Fishman, E., Washington, S., Haworth, N., 2013. Bike share: a synthesis of the literature. Transport Rev. 33, 148–165. https://doi.org/10.1080/01441647.2013.775612.

Fishman, E., Washington, S., Haworth, N., Mazzei, A., 2014. Barriers to bikesharing: an analysis from Melbourne and Brisbane. J. Transport Geogr. 41, 325–337. https://doi.org/10.1016/j.jtrangeo.2014.08.005.

Fitt, H., Curl, A., 2020. The early days of shared micromobility: a social practices approach. J. Transport Geogr. 86, 102779 https://doi.org/10.1016/j.jtrangeo.2020.102779.

Fulton, L.M., 2018. Three revolutions in urban passenger travel. Joule 2, 575–578. https://doi.org/10.1016/j.joule.2018.03.005.

Galatoulas, N.-F., Genikomsakis, K.N., Ioakimidis, C.S., 2020. Spatio-Temporal trends of E-bike sharing system deployment: a review in Europe, north America and asia. Sustainability. https://doi.org/10.3390/su12114611.

Glavic, D., Trpkovi, A., Milenkovi, M., Jevremovi, S., 2021. The E-scooter potential to change urban mobility-belgrade case study. E-Scoot. Potential Change Urban Mobility—Belgrade Case Study. https://doi.org/10.3390/su13115948.

Glenn, J., Bluth, M., Christianson, M., Pressley, J., Taylor, A., Macfarlane, G.S., Chaney, R.A., 2020. Considering the potential health impacts of electric scooters: an analysis of user reported behaviors in provo, Utah. Int. J. Environ. Res. Publ. Health 17. https://doi.org/10.3390/ijerph17176344.

Goodman, A., Green, J., Woodcock, J., 2014. The role of bicycle sharing systems in normalising the image of cycling: an observational study of London cyclists. J. Transport Health 1, 5–8. https://doi.org/10.1016/j.jth.2013.07.001.

Hardt, C., Bogenberger, K., 2019. Usage of e-scooters in urban environments. Transport. Res. Procedia 37, 155–162. https://doi.org/10.1016/j.trpro.2018.12.178.

Hipp, J.A., Dodson, E.A., Lee, J.A., Marx, C.M., Yang, L., Tabak, R.G., Hoehner, C., Marquet, O., Brownson, R.C., 2017. Mixed methods analysis of eighteen worksite policies, programs, and environments for physical activity. Int. J. Behav. Nutr. Phys. Activ. 14, 1–10. https://doi.org/10.1186/s12966-017-0533-8.

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.

Hosseinzadeh, A., Algomaiah, M., Kluger, R., Li, Z., 2021. E-scooters and sustainability: investigating the relationship between the density of E-scooter trips and characteristics of sustainable urban development. Sustain. Cities Soc. 66, 102624 https://doi.org/10.1016/j.scs.2020.102624.

Hyvönen, K., Repo, P., Lammi, M., 2016. Light electric vehicles: substitution and future uses. Transport. Res. Procedia 19, 258–268. https://doi.org/10.1016/j.trpro.2016.12.085.

IDESCAT, 2020. Idescat. The municipality in figures. Barcelona [WWW Document]. URL. https://www.idescat.cat/emex/?id=080193&lang=en.

Jiao, J., Bai, S., 2020. Understanding the shared e-scooter travels in Austin, TX. ISPRS Int. J. Geo-Inf. 9 (2), 135.

Johnson, M., Rose, G., 2015. Extending life on the bike: electric bike use by older Australians. J. Transport Health 2, 276–283. https://doi.org/10.1016/j.jth.2015.03.001.

Kaplan, S., Wrzesinska, D.K., Prato, C.G., 2018. The role of human needs in the intention to use conventional and electric bicycle sharing in a driving-oriented country. Transport Pol. 71, 138–146. https://doi.org/10.1016/j.tranpol.2018.09.010.

Kopplin, C.S., Brand, B.M., Reichenberger, Y., 2021. Consumer acceptance of shared e-scooters for urban and short-distance mobility. Transport. Res. Part Transp. Environ. 91, 102680 https://doi.org/10.1016/j.trd.2020.102680.

Krauss, K., Krail, M., Axhausen, K.W., 2022. What drives the utility of shared transport services for urban travellers? A stated preference survey in German cities. Travel Behav. Soc. 26, 206–220. https://doi.org/10.1016/j.tbs.2021.09.010.
Laa, B., Leth, U., 2020. Survey of E-scooter users in Vienna : who they are and how they ride. J. Transport Geogr. 89, 102874 https://doi.org/10.1016/j.jtrangeo.2020.102874.
Lazarus, J., Pourquier, J.C., Feng, F., Hammel, H., Shaheen, S., 2020. Micromobility evolution and expansion: understanding how docked and dockless bikesharing models complement and compete – a case study of San Francisco. J. Transport Geogr. 84, 102620 https://doi.org/10.1016/j.jtrangeo.2019.102620.
Li, A., Zhao, P., Haitao, H., Mansourian, A., Axhausen, K.W., 2021. How did micro-mobility change in response to COVID-19 pandemic? A case study based on spatial-temporal-semantic analytics. Comput. Environ. Urban Syst. 90, 101703 https://doi.org/10.1016/j.compenvurbsys.2021.101703.
Li, H., Yuan, Z., Novack, T., Huang, W., Zipf, A., 2022. Understanding spatiotemporal trip purposes of urban micro-mobility from the lens of dockless e-scooter sharing. Comput. Environ. Urban Syst. 96, 101848 https://doi.org/10.1016/j.compenvurbsys.2022.101848.
Li, W., Kamargianni, M., 2018. Providing quantified evidence to policy makers for promoting bike-sharing in heavily air-polluted cities: a mode choice model and policy simulation for Taiyuan-China. Transport. Res. Part Policy Pract. 111, 277–291. https://doi.org/10.1016/j.tra.2018.01.019.
López-Dóriga, I., Vich, G., Koch, S., Khomenko, S., Marquet, O., Roig-Costa, O., Daher, C., Rasella, D., Nieuwenhuijsen, M., Mueller, N., 2022. Health impacts of electric micromobility transitions in Barcelona: a scenario analysis. Environ. Impact Assess. Rev. 96, 106836 https://doi.org/10.1016/J.EIAR.2022.106836.
Maciejewska, M., Marquet, O., Miralles-Guasch, C., 2019. Changes in gendered mobility patterns in the context of the Great Recession. J. Transport Geogr. 79, 102478 https://doi.org/10.1016/j.jtrangeo.2019.102478.
Marquet, O., Miralles-Guasch, C., 2016. City of Motorcycles. On how objective and subjective factors are behind the rise of two-wheeled mobility in Barcelona. Transport Pol. 52, 37–45. https://doi.org/10.1016/j.tranpol.2016.07.002.
Marquet, O., Miralles-Guasch, C., 2015. The Walkable city and the importance of the proximity environments for Barcelona's everyday mobility. Cities 42, 258–266. https://doi.org/10.1016/j.cities.2014.10.012.
Marquet, O., Miralles-Guasch, C., 2014. The use of proximity in Barcelona. An analysis through daily trvale times. Ciudades 17, 99–120.
Marshall, A., 2018. 2018 was the year of the scooter. What happens now? WIRED [WWW Document] Wired. URL. https://www.wired.com/story/2018-year-of-the-scooter-what-happens-2019/.
McKenzie, G., 2019. Spatiotemporal comparative analysis of scooter-share and bike-share usage patterns in Washington, D.C. J. Transport Geogr. 78, 19–28. https://doi.org/10.1016/j.jtrangeo.2019.05.007.
Merlin, L.A., Yan, X., Xu, Y., Zhao, X., 2021. A segment-level model of shared, electric scooter origins and destinations. Transport. Res. Part Transp. Environ. 92, 102709 https://doi.org/10.1016/j.trd.2021.102709.
Milakis, D., Gebhardt, L., Ehebrecht, D., Lenz, B., 2020. 19.Is micro-mobility sustainable? An overview of implications for accessibility, air pollution, safety, physical activity and subjective wellbeing. Handb. Sustain. Transp. 180.
Mitra, R., Hess, P.M., 2021. Who are the potential users of shared e-scooters? An examination of socio-demographic, attitudinal and environmental factors. Travel Behav. Soc. 23, 100–107. https://doi.org/10.1016/j.tbs.2020.12.004.
Mouratidis, K., 2022. Bike-sharing, car-sharing, e-scooters, and Uber: who are the shared mobility users and where do they live? Sustain. Cities Soc. 86, 104161 https://doi.org/10.1016/j.scs.2022.104161.
Murphy, E., Usher, J., 2015. The role of bicycle-sharing in the city: analysis of the Irish experience. Int. J. Sustain. Transp. 37–41. https://doi.org/10.1080/15568318.2012.748855.
NACTO, 2019. Bike Share. Station Siting Guide.
Nikiforiadis, A., Paschalidis, E., Stamatiadis, N., Raptopoulou, A., Kostareli, A., Basbas, S., 2021. Analysis of attitudes and engagement of shared e-scooter users. Transport. Res. Part Transp. Environ. 94, 102790 https://doi.org/10.1016/j.trd.2021.102790.
Ognissanto, F., Hopkin, J., Stevens, A., Millard, K., Ognissanto, Flora, 2018. Innovative Active Travel Solutions and Their Evaluation. The Future of Transport.
Olsen, S.O., 2007. Repurchase loyalty: the role of involvement and satisfaction. Psychol. Market. 24, 315–341. https://doi.org/10.1002/mar.20163.
Patil, M., Majumdar, B.B., 2021. Prioritizing key attributes influencing electric two-wheeler usage: a multi criteria decision making (MCDM) approach – a case study of Hyderabad, India. Case Stud. Transp. Policy 9, 913–929. https://doi.org/10.1016/j.cstp.2021.04.011.
Paviotti, M., Vogiatzis, K., 2012. On the outdoor annoyance from scooter and motorbike noise in the urban environment. Sci. Total Environ. 430, 223–230. https://doi.org/10.1016/j.scitotenv.2012.05.010.
Plazier, P.A., Weitkamp, G., van den Berg, A.E., 2017. The potential for e-biking among the younger population: a study of Dutch students. Travel Behav. Soc. 8, 37–45. https://doi.org/10.1016/j.tbs.2017.04.007.
Polis, 2019. Macro Managing Micro Mobility. Taking the Long View on Short Trips. Ixelles, Belgium.
Popovich, N., Gordon, E., Shao, Z., Xing, Y., Wang, Y., Handy, S., 2014. Experiences of electric bicycle users in the sacramento, California area. Travel Behav. Soc. 1, 37–44. https://doi.org/10.1016/j.tbs.2013.10.006.
Reck, D.J., Axhausen, K.W., 2021. Who uses shared micro-mobility services? Empirical evidence from Zurich, Switzerland. Transport. Res. Part D 94, 102803. https://doi.org/10.1016/j.trd.2021.102803.
Reck, D.J., Martin, H., Kay, W., 2022. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transport. Res. Part Transp. Environ. 102 https://doi.org/10.1016/J.TRD.2021.103134.
Reilly, K.H., Noyes, P., Crossa, A., 2020. From non-cyclists to frequent cyclists: factors associated with frequent bike share use in New York City. J. Transport Health 16, 100790. https://doi.org/10.1016/j.jth.2019.100790.
Rejali, S., Aghabayk, K., Mohammadi, A., Shiwakoti, N., 2021. Assessing a priori acceptance of shared dockless e-scooters in Iran. Transport. Res. Part Transp. Environ. 100, 103042 https://doi.org/10.1016/j.trd.2021.103042.
Ricci, M., 2015. Bike sharing: a review of evidence on impacts and processes of implementation and operation. Res. Transp. Bus. Manag. 11 https://doi.org/10.1016/j.rtbm.2015.03.003.
Roig-Costa, O., Gómez-Varo, I., Cubells, J., Marquet, O., 2021. La movilidad post pandemia: perfiles y usos de la micromovilidad en Barcelona. Rev. Transp. Territ. 25, 72–96. https://doi.org/10.34096/rtt.i25.10958.
Sanders, R.L., Branion-Calles, M., Nelson, T.A., 2020. To scoot or not to scoot: findings from a recent survey about the benefits and barriers of using E-scooters for riders and non-riders. Transport. Res. Part Policy Pract. 139, 217–227. https://doi.org/10.1016/j.tra.2020.07.009.
Sardi, P., Dutra, R., Macke, J., Sarate, J., 2019. "Green, but not as green as that": an analysis of a Brazilian bike-sharing system. J. Clean. Prod. 217 https://doi.org/10.1016/j.jclepro.2019.01.240.
Scheiner, J., Holz-Rau, C., 2017. Women's complex daily lives: a gendered look at trip chaining and activity pattern entropy in Germany. Transportation. https://doi.org/10.1007/s11116-015-9627-9.
Sellaouti, A., Arslan, O., Hoffmann, S., München, U.D.B., 2019. Anis Sellaouti, oytun arslan, silja hoffmann. IEEE Xplore 18–22.
Shaheen, S., Cohen, A., 2019. Shared Micromobility Policy Toolkit. Docked and Dockless Bike and Scooter Sharing. https://doi.org/10.7922/G2TH8JW7.
Shaheen, S., Martin, E., Cohen, A., Chan, N., Pogodzinsk, M., Martin, E., Chan, N., 2014. Public bikesharing in North America during a period of rapid expansion: understanding business models, industry trends & user impacts. Mineta Transp. Inst. Rep. 12-29.
Shaheen, S., Zhang, H., Martin, E., Guzman, S., 2011. China's Hangzhou Public Bicycle: understanding early adoption and behavioral response to bikesharing. Transport. Res. Rec. 33–41. https://doi.org/10.3141/2247-05.
Sheng, N., Zhou, X., Zhou, Y., 2016. Science of the Total Environment Environmental impact of electric motorcycles: evidence from traffic noise assessment by a building-based data mining technique. Sci. Total Environ. 554 (555), 73–82. https://doi.org/10.1016/j.scitotenv.2016.02.148.
Simsekoglu, Ö., Klöckner, C., 2019. Factors related to the intention to buy an e-bike: a survey study from Norway. Transport. Res. F Traffic Psychol. Behav. 60, 573–581. https://doi.org/10.1016/j.trf.2018.11.008.
Soriguera, F., Jiménez-Meroño, E., 2020. A continuous approximation model for the optimal design of public bike-sharing systems. Sustain. Cities Soc. https://doi.org/10.1016/j.scs.2019.101826.
Spinney, J., 2020. Understanding Urban Cycling: Exploring the Relationship between Mobility, Sustainablity and Capital. Routeledge.
Teixeira, J.F., Silva, C., Moura e Sá, F., 2020. Empirical evidence on the impacts of bikesharing: a literature review. Transport Rev. 0, 1–23. https://doi.org/10.1080/01441647.2020.1841328.
The Nunatak Group, 2019. New Urban Mobility.
Van Exel, N.J.A., Rietveld, P., 2009. Could you also have made this trip by another mode? An investigation of perceived travel possibilities of car and train travellers on the main travel corridors to the city of Amsterdam, The Netherlands. Transport. Res. Part Policy Pract. 43, 374–385. https://doi.org/10.1016/j.tra.2008.11.004.
Wang, K., Qian, X., Fitch, D.T., Lee, Y., Malik, J., Circella, G., 2022. What travel modes do shared e-scooters displace? A review of recent research findings. Transport Rev. https://doi.org/10.1080/01441647.2021.2015639.
Weiss, M., Dekker, P., Moro, A., Scholz, H., Patel, M.K., 2015. On the electrification of road transportation – a review of the environmental, economic, and social performance of electric. Transp. Res. PART D 41, 348–366. https://doi.org/10.1016/j.trd.2015.09.007.
Younes, H., Zou, Z., Wu, J., Baiocchi, G., 2020. Comparing the temporal determinants of dockless scooter-share and station-based bike-share in Washington, D.C. Transport. Res. Part Policy Pract 134, 308–320. https://doi.org/10.1016/j.tra.2020.02.021.
Zhu, R., Zhang, X., Kondor, D., Santi, P., Ratti, C., 2020. Understanding spatio-temporal heterogeneity of bike-sharing and scooter-sharing mobility. Comput. Environ. Urban Syst. 81, 101483 https://doi.org/10.1016/j.compenvurbsys.2020.101483.