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Disrupted intermodality: Examining adaptation strategies to public transport e-scooter bans in Barcelona

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ABSTRACT

Electric scooters (e-scooters) have changed urban mobility by offering a dynamic solution to the critical "first and last mile" problem, connecting individuals from their homes to public transport and their final destinations. Despite their growing popularity, e-scooters navigate through a landscape of shifting legal frameworks, highlighting the urgency for policies that not only harness their potential but also address their inherent challenges. This study aims to shed light on the intermodal practices and demographics of e-scooters users in Barcelona, explores the potential impacts of regulatory changes on established transport habits, and assesses the adaptability of users to changing transportation options. Through a self-reported survey of 311 private e-scooter users, we find a notable prevalence of young men from lower socioeconomic backgrounds engaging in intermodal travel, primarily for employment purposes. To better understand how e-scooter riders integrate the device in their daily mobility strategies, we introduce the Intermodality Ratio (IR). A Generalized Linear Model (GLM) is then used to identify key demographic, socioeconomic, and geographic predictors of the IR, revealing place of residence as the most significant factor influencing intermodal behavior. Finally, we analyze participants' anticipated behavioral shifts in response to the upcoming ban using a Multinomial Logistic Regression (MLR) model, which explores the sociodemographic factors affecting the likelihood of adopting alternative transport strategies. These findings contribute to the limited understanding of e-scooter utilization and intermodal practices, particularly within the context of public transit, offering insights into how transport policies can more effectively accommodate emerging mobility solutions.

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1. Introduction

Since their appearance in 2017, personal mobility vehicles (PMV) have continued to gain popularity expanding the number of transportation options available to urban travelers. Among these, electric scooters (hereafter *e-scooters*) have become the most prevalent alternative. Their high levels of comfort, convenience, and electric-assistance have fundamentally reshaped the relation with traditional modes of transport, either replacing or complementing them. The fact that e-scooters enable users for smoothly covering short distances without the exertion of physical effort (Gibson et al., 2022), for instance, has often translated into the replacement of already existent modes of transport for such urban short trips (Wang et al., 2023).

Despite the frequent recognition of intermodality as a significant advantage of micromobility vehicles, there remains a notable gap in empirical studies addressing specifically e-scooters' intermodal uses (Moinse et al., 2024; Zuniga-Garcia et al., 2022). This research gap could be attributed to the novelty of these vehicles and to the lack of standardized methodologies (Oeschger et al., 2020). Specifically, the existing literature lacks comprehensive exploration in areas such as quantitative approaches to usage patterns, user demographics, and trip purposes (Ensor et al., 2021; Schlueter-Langdon et al., 2021), which highlights a pressing need for more focused academic investigations addressing these shortcomings. Beyond the challenge of fully grasping intermodality, there's also a clear gap in understanding how to oversee and regulate micromobility devices effectively (Zhang et al., 2024). The rapid evolution of these technologies often clashes with existing city regulations, primarily due to concerns about public space use and safety (Fearnley, 2020). The scarcity of comprehensive research and data exacerbates this issue, complicating the development of informed regulations. Consequently, cities may resort to hastily made, and sometimes premature, policies to manage these innovations.

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This situation underscores the urgent need for a deeper insight into the interplay between technological advancements and regulatory measures. Recognizing the significance of informed policymaking is essential for leveraging the benefits of new mobility options while ensuring their safe, accessible, and sustainable integration into urban and suburban areas (De Vos, 2024). Addressing both these knowledge gaps is crucial for progressing toward policies that can fully exploit the advantages of multimodality and micromobility.

The aim of this study is therefore to contribute to bridging the knowledge gap regarding the integration between privately-owned e-scooters and public transport. By looking into the purposes, satisfaction, and temporal patterns of e-scooter integration with public transport, this research sheds light on the subjective and practical dimensions of micromobility choices among (sub)urban commuters. Situated in a regional context, our analysis offers (1) a comprehensive understanding of the behaviors and preferences of private e-scooter intermodal users. This enables us to explore the dynamics of private e-scooter and public transport integration, revealing insights into users' predominant preferences for e-scooters as a complementary mode to public transportation, and the demographic factors influencing exclusive intermodal e-scooter usage. Such findings are important to understand the evolving landscape of urban mobility, highlighting the importance of considering user satisfaction and behavioral tendencies in the planning and regulation of micromobility solutions. Our research also evaluates (2) the resilience of these modal preferences in the face of policy interventions, an important consideration given the constantly evolving legislative and regulatory frameworks governing micromobility, especially in cities experiencing rapid micromobility adoption and integration challenges (Grosshuesch, 2020). Studying the impact of a regulatory change that consists of an effective ban of bringing e-scooters on public transport vehicles, we can understand how micromobility users adapt and change their everyday behavior. Through their anticipated behavioral shifts, we explore their decision making when having to deal with a sudden change in transport conditions. This allows us to deepen our understanding of the individual tradeoffs regarding cost, time, and convenience among a population group -micromobility users- that has already demonstrated a proven capacity to invest in new travel behaviors and transportation modes.

To that end, the study uses data from a travel survey conducted in Barcelona, Spain, and aims to provide a comprehensive overview of existing e-scooter intermodal practices. It explores e-scooter intermodal user profile and their trip purposes, examines the temporal patterns linked to subjective evaluation of intermodality stages, and investigates the most prominent socioeconomic intermodality predictors. Additionally, the study discusses the stated behavioral changes, and its associated socioeconomic factors, in response to an e-scooter prohibition challenging the essence of e-scooter intermodality.

2. Background

2.1. Intermodality: Trends in e-scooter and public transport integration

Intermodality, as defined by Polzin (2017), involves using multiple means of travel to achieve a given trip, a practice that has been proven essential for optimizing transportation systems, enhancing connectivity, and improving overall travel efficiency. The combination of e-scooters with public transportation networks has significantly boosted first and last-mile connectivity (Böcker et al., 2020; Zuniga-Garcia et al., 2022), offering an unprecedented level of flexibility and accessibility within urban transport networks. This integration has also contributed to extending service areas available within transit isochrones (Abduljabbar et al., 2021; Kostrzewska & Macikowski, 2017), effectively mitigating the limitations of public transportation. In suburban areas (Oostendorp & Gebhardt, 2018), where travel distances for accessing transit stops tend to be longer (Cervero et al., 2013), this expansion is particularly beneficial in improving the transport system efficiency, since it greatly contributes to the public transport system's rigidity reduction. However, while e-scooters are increasingly popular and have been introduced in multiple cities around the world, previous literature has acknowledged there is a notable gap in understanding its integration with existing public transportation services (Oeschger et al., 2023).

On a general level, prior studies have shed light on intermodal e-scooter trips in Europe and the United States, with a primary focus on shared schemes. Data from France shows that between a quarter and a fifth of e-scooter trips are combined with metro and train services (66t-Bureau de recherche, 2020; de Bortoli & Christoforou, 2020; Pestour, 2019; Richer, 2021). Specifically in Paris, prior to the end of e-scooter sharing license operating, Møller et al. (2020) found that 70% of Lime users and 60% of Voi users occasionally connected e-scooters with public transport. In Germany, Edel et al. (2021) reported that 55.6% of e-scooter users integrated the personal devices with public transport, and similar trends were observed in Oslo, where Fearnley (2020) and Aarhaug et al. (2023) highlighted similar levels of integration of e-scooters with public transport modes. Results from Laa and Leth (2020) in Vienna also show that up to 80% of the riders use their personal e-scooter in combination with public transport sometimes or often. However, a study by Moran et al. (2020) also in Vienna shows that the areas where shared e-scooters were available in the city (mostly the inner parts of the city where public transport coverage is very good), rather than being used for the first or last mile shared e-scooters represented a competition to public transport. Similarly, in their study in Belgrade, Glavic et al. (2021) noted that more than half of the respondents (53.6%) never or rarely combined the use of e-scooters and public transport, although it is not clear whether these are shared or owned devices. Interestingly, in their literature review on the utilization and demographics of e-scooters users, Moinse et al. (2024) reveal that, in Europe, approximately 70% of intermodal trips involving e-scooters are associated to some form of public transportation. This percentage, however, seemed to drop in other parts of the world, as e-scooters' higher rates of complementarity were related to private cars.

2.2. Sociodemographic profiles and travel patterns

From a sociodemographic perspective, existing literature has generally characterized e-scooter users as young, employed men (Laa & Leth, 2020; Roig-Costa, Miralles-Guasch, et al., 2024), with high levels of education (Arias-Molinares & Carlos García-Palomares, 2020; Christoforou et al., 2021; Merlin et al., 2021), and higher income levels (Elmashhara et al., 2022; Liao & Correia, 2022). However, a thorough characterization of users that tend to combine e-scooter with public transportation is still missing (Ensor et al., 2021). Through a comparative analysis based on vehicle availability data for shared e-scooters conducted across 124 European cities, Li et al. (2024) recently revealed a higher proportion of native residents and young people positively influenced integration ratios with public transport, findings that align with those by Montes et al. (2023), who found that young individuals in Rotterdam preferred to select shared micro-mobility as a connecting tool. Similarly, in their study in Dublin, Oeschger et al. (2023) indicated a notable preference for micromobility - including private and shared micromobility- and public transport among young individuals (under 35 years old) and male respondents, and Zuniga-Garcia et al. (2022) demonstrated that a percentage of shared e-scooter users integrate the devices with bus transit systems, particularly on university campuses, where individuals tend to be younger. Given this students' inclination toward using e-scooter sharing systems (Hong et al., 2023), Nikiforiadis et al. (2023) focused on university students and examined their willingness to use shared e-scooters for intermodal trips. Their results indicate that as the distance from the city center increases, satisfaction levels decrease for both shared e-scooter availability and the quality of public transport services.

Recent literature has also started to distinguish the motivations behind e-scooter usage, highlighting that private e-scooter trips are often associated with work-related travel (Laa & Leth, 2020; Roig-Costa et al., 2021), whereas shared e-scooters are predominantly used for leisure purposes (Bieliński et al., 2021; McKenzie, 2019). However, while this differentiation adds an important layer to understanding the role of e-scooters, an issue that remains especially understudied is how these varying motivations impact the integration of e-scooters with public transport systems (Ensor et al., 2021). In one of the few studies available, Edel et al. (2021) uncovered that approximately 44.4% of intermodal e-scooter users in Germany ride an e-scooter for commuting to work, demonstrating alignment between the preferences of users and the technical capabilities of e-scooters, making them suitable for commuting purposes. In their study, e-scooters features such as speed and range are shown to be highly advantageous and well-suited for commuting needs, what increased the acceptance of intermodal travel. As Kager et al. (2016) anticipated in their study, this indicates that the hybrid combination of e-scooters with public transit for commuting purposes can effectively offer significant benefits in terms of efficiency and convenience.

2.3. The rise of private e-scooters and the role of regulations in shaping intermodality

To date, the limited body of research on intermodal e-scooters has been mainly focused on their role in enhancing intermodality with shared services. However, the shift toward personal ownership is increasingly prevalent, both driven by city bans on shared e-scooter services (Roig-Costa, Miralles-Guasch, et al., 2024) and by individuals' desire for the flexibility of not relying on third-party services. Such a trend is facilitated by the inherent lightweight nature of these vehicles, making them an appealing option for personal mobility. As noted in Moinse et al. (2024), a distinctive characteristic of privately-owned e-scooters emerges when compared to shared e-scooters systems: nearly all users of privately-owned e-scooters rely on them for both the access and egress stages of their trip. In contrast to shared e-scooter users, who frequently switch to a different mode for their return trip (66t-Bureau de recherche, 2020), privately-owned e-scooters users enjoy the advantage of easily bring the device onto trains, especially during peak times, allowing travelers not only closing the gap in both stages, but also to access a broader range of destinations after leaving the public transport alternative.

However, the impact of private e-scooter ownership on our understanding of e-scooter intermodality remains significantly underexplored. Furthermore, there's an even scarcer body of research examining how regulatory changes affect these behaviors, whether positively - such as train systems reserving space for e-scooter users - or negatively, exemplified by cities banning shared e-scooters (e.g., Paris) or prohibiting e-scooters on trains (e.g., Barcelona). Yet, this aspect is crucial, as the use and demand for e-scooters are deeply affected by the legislative frameworks unique to each city or region (Roig-Costa, Miralles-Guasch, et al., 2024). As the adoption of privately-owned e-scooters for daily mobility becomes increasingly common in urban and suburban areas, preliminary studies are starting to investigate how these e-scooters are used alongside public transport, underscoring the need for more nuanced research in this area (Mitropoulos et al., 2023; Moinse et al., 2024).

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, 2022). Its extensive public transport network, featuring metro, train, tram, and bus services, extends its reach well into the metropolitan region, facilitating mobility for a significant catchment area beyond the city. At a metropolitan level, the main mode of travel for trips is active mobility (50.7%) followed by private vehicles (34.2%), and public transport with 15.1% (EMEF, 2022). Regarding e-scooters, 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), regulation also implemented in Paris later in 2023 (Chrisafis, 2023). The measure, however, resulted in a rapid rise in the popularity of privately owned e-scooters at an urban level, going from 70,803 trips in 2019 to 127,572 in 2022, which represents an 80.2% increase (EMEF, 2022). At a metropolitan scale, trips involving an e-scooter represent a 0.7% of the total amount of trips the totality of them involving a privately-owned device (EMEF, 2022).

Additionally, the specific context of e-scooter usage presents a noteworthy case, highlighting a growing trend among urban commuters: the integration of privately-owned e-scooters with public transportation systems. This trend caught administrations and public transport operators unprepared for their absorption, prompting intense debates regarding space management and safety concerns on board. In response to these concerns, metropolitan authorities promulged a regulation on 1st February 2023 prohibiting the boarding of e-scooter on public transportation systems (ATM, 2023). This legislative action underscores the critical need for adaptive regulatory frameworks that can accommodate the evolving landscape of urban mobility while addressing safety and efficiency within public transport networks.

3.2. Data sources

At the end of January 2023, 311 intermodal users of e-cooters and public transport were surveyed to analyze their transport habits. The questionnaire, which followed a CAPI (Computer Assisted Personal Interviewing) methodology, was carried out in the vicinity of different public transport stations/stops in the city of Barcelona (Supplementary Table 1), to ensure that the subjects surveyed were indeed intermodal users of e-scooters and public transport. In order to organize the fieldwork and obtain a sample of users who use different typologies of public transport, recruitment was organized in and around 9 distinguished transportation hubs in the city. Participants were randomly intercepted while using an e-scooter as part of a longer public transport trip, by using a convenience sampling approach. While this is a non-probabilistic sampling method (the only two criterions were being an intermodal e-scooter traveler and whether people were willing to participate), it is a cost-effective, faster, and easier way to collect data. In total, 311 surveys were conducted, over a total period of 8 days, with private e-scooter above 16 years of age (which is the minimum age allowed to ride an e-scooter), who were living and/or working in Barcelona. The survey questionnaire was organized into four distinct blocks. The first block included questions on e-scooter and public transport use, such as daily frequency, travel times, and purposes. A second block focused on travel satisfaction, using the Travel Satisfaction Scale (STS) (Ettema et al., 2011) as the main measurement item. The third block complemented the previous two with questions to determine the socio-demographic characteristics of the respondents. A final block focused specifically on the previously announced ban on e-scooters in public transport and inquired users about how they planned to adapt to the new legal framework.

3.3. Statistical methods

First, aiming to better understand to what extent intermodal e-scooter riders integrate the device in their daily mobility strategies, we provide an initial overview of the intermodality phenomenon. To that end, Figure 1 presents the Intermodality Ratio (IR), a formula representing the fraction of e-scooter trips made in combination with public transport over all the e-scooter trips generated. The variables used to calculate this ratio were derived from our survey, specifically questions related to the total number of e-scooter trips by respondents (i.e., *How many e-scooter trips did you realize yesterday?*), and the frequency of e-scooter usage in conjunction with public transport options (i.e., *In how many of those trips did you introduce the e-scooter into the public transport?*). This approach allows us to quantitatively assess the extent to which e-scooters are integrated into broader urban transport strategies:

Second, to characterize intermodal users, we used descriptive statistics that include variables on gender (Woman, Man, Non-binary, or Prefer not to say), age (<18, 18-24, 25-34, 35-44, 45-54, or >55), professional status (Employed, Unemployed, or Student), level of education (None or Primary, Secondary, or University), access to vehicles (No; Yes, car; Yes, motorbike; or Yes, both) and place of residency (Barcelona, 1st metropolitan ring, or Others). To explore the underlying purposes for integrating e-scooter with public transport combination participants were asked to answer a question regarding the primary purpose of the intercepted trip (i.e., *Which is the purpose of this trip?*). This allowed for the collection of direct responses that could be quantitatively analyzed to discern patterns in the use of e-scooters as a component of intermodal transport strategies. Respondents were given a set of predefined categories to choose from, such as commuting, leisure, personal errands, shopping, and others, ensuring a structured and consistent set of data for subsequent analysis. Additionally, respondents were asked to provide both the origin and destination of their trips, which allowed us to categorize the scale of the trip as either intermunicipal or intramunicipal. This detailed information provided a clearer

$$\textbf{Intermodality Ratio} = \frac{\textbf{Trips combining e} - \textbf{scooter} + \textbf{PT}}{\textbf{Total e} - \textbf{scooter trips}}\ \textbf{x 100}$$

Figure 1. Intermodality ratio (IR) formula.

picture of how e-scooter and public transport combinations are employed across different spatial contexts.

Third, the methodological approach includes a quantitative assessment of the time spent on each stage of the intermodal trip compared with an evaluation of their satisfaction with each stage of the trip (on a scale from 0 to 10). Participants were asked to report the duration of their e-scooter and public transport stages in minutes, which were then categorized as short, medium, and long, according to the scale of the trip. As reported by the EMEF (2023), the average time for public transport in Barcelona is 53 min for intermunicipal trips and 26 min for intramunicipal trips. Given that difference, it was judged critical to differentiate accordingly between intemunicipal and intramunicipal travelers to ensure a more precise analysis of each trip's characteristics and their impact on user experience. Thus, using these average times we determined the thresholds for each type of trip. For intermunicipal trips, stages were calculated as follows: (i) short stages: less than 40 min, which represents approximately 25% less than the average ($53 - 25\% \approx 40$ min); (ii) medium stages: between 40 and 70 min, range covering trips around the average, allowing for a variation from 25% below to 25% above the average ($53 - 25\% \approx 40$ min, $53 + 25\% \approx 70$ min); and (iii) long stages: more than 70 min, set at approximately 25% above the average. Similarly, the thresholds for intramunicipal trips were adjusted as follows: (i) short stages: less than 20 min. This threshold is about 25% below the average ($26 - 25\% \approx 20$ min); (ii) medium stages: between 20 and 35 min, covering a margin from 25% below to 25% above the average ($26 - 25\% \approx 20$ min, $26 + 25\% \approx 35$ min); and (iii) long stages: more than 35 min, representing trips significantly longer than the average (25% above the mean). Regarding e-scooter stages, we used data extracted from Cubells et al. (2023), which demonstrated e-scooter trips in Barcelona to have an average duration of 8.34 min. According to that and considering that intermodal e-scooter trips involve two e-scooter stages, the average duration in our analysis was computed as 8.34 times two = 16.68 min. Therefore, thresholds were calculated as follows: (i) short stages: less than minutes 12.5 min, which is approximately 25% less than the average ($16.68 - 25\% \approx 12.5$ min); (ii) medium trips: between 12.5 and 21 min, covering a range of 25% below to 25% above the average ($16.68 - 25\% \approx 12.5$ min, $16.68 + 25\% \approx 21$ min); and (iii) long stages: more than 21 min, representing trips that are at least 25% longer than the average. This dual approach allowed for the analysis of the relationship between the objective time investment in travel and the subjective satisfaction ratings, providing insights into the relationship between duration and perceived quality of experience in intermodal transport.

Fourth, given the IR's continuous and bounded nature (values ranging between 0 and 1), we employed a Generalized Linear Model (GLM) to analyze the propensity of participants to combine the e-scooter with public transportation over their total use of e-scooter. Additionally, the right-skewed distribution of the IR required a model capable of capturing this skewness, which a standard linear regression could not effectively handle. Predictors included in the model spanned demographic factors (age and gender), socioeconomic factors (education level, professional status, and access to a vehicle), and geographical factors (place of residence), all of them known to potentially influence travel behavior. GLM allowed us to simultaneously model these different types of variables while maintaining flexibility in the assumptions about the relationship between the predictors and the IR.

As the final element of our analysis, we analyzed the participants self-reported anticipated behavioral shifts in response to the upcoming e-scooter ban on public transport. Because we timed data collection to happen exactly one week prior to the implementation of the ban, we were able to assess participants intended replacement strategies for the part of their trip facilitated by e-scooters. Specifically, we asked: "In view of this upcoming prohibition, how do you think it will affect your current travel in the frame of this specific trip?". Figure 3 indicates the various transport alternatives that respondents were considering replacing the e-scooter stage of their trip with. Responses included (1) I won't do the trip; (2) I will replace the e-scooter with walking; (3) I will replace the e-scooter with a privately-owned bicycle; (4) I will replace the e-scooter with a shared bicycle; (5) I will replace the e-scooter with public transport; (6) I will park the e-scooter in the station; (7) I will do the full trip by car; (8) I will do the same as now, no matter the prohibition; (9) I still don't know; and (10) I will do the full trip with the e-scooter.

Additionally, in an attempt to explore which respondents will adopt each strategy, Table 5 presents a Multinomial Logistic Regression (MLR) model examining the likelihood of affected travelers adapting a given strategy compared to choosing to use the e-scooter door to door in response to the introduction of the ban. The model examines several sociodemographic factors, including age, gender, education level, professional status, vehicle access, and place of residency, to understand their influence on the adoption of alternative travel strategies. Strategies representing less than a 3% of the total responses were excluded from the analysis. Analyses were conducted using IBM SPSS v21.

4. Results

4.1. Intermodality and e-scooter

On average, participants reported making about 3.52 e-scooter trips per day, of which approximately 2.58 were indeed intermodal (i.e., involving the use of e-scooters combined with public transport). The higher standard deviation in total e-scooter trips (2.65) compared to intermodal trips (2.26) suggests that while all users engage in intermodal behavior, the extent and frequency of their overall e-scooter usage vary more widely (Table 1). The Intermodality Ratio (IR), which represents the fraction of e-scooter trips made in combination with public transport over all the e-scooter trips generated (Figure 1), stands at 0.73, which indicates that, on average, 73% of the total e-scooter trips made by users in our sample are made in combination with public

Table 1. Summary of e-scooter trips made by participants in the sample ($N = 311$).

	Sum	Mean	Standard deviation
Total E-Scooter Trips	1091	3.52	2.655
Intermodal E-Scooter Trips	800	2.58	2.261
Intermodality Ratio (IR)	–	0.73	–

Table 2. Sociodemographic and trip characteristics of the sample.

	Mean (cont. var)	N	(%)
Gender			
Woman		109	35.0
Man		196	63.0
Age	30.0		
<18		25	8.0
18–24		102	32.8
25–34		81	26.0
35–44		63	20.3
45–54		30	9.6
>55		10	3.2
Professional status			
Employed		255	82.0
Unemployed		11	3.5
Student		45	14.5
Level of education			
None or primary		48	15.4
Secondary		163	52.4
University		95	30.5
Access to vehicle			
No		209	67.2
Yes, car		81	26.0
Yes, motorbike		4	1.3
Yes, both		15	4.8
Place of residency			
Barcelona		110	35.4
RMB 1		64	20.6
RMB 2		22	7.1
Others		112	36.0
Trip scale			
Intermunicipal		244	79.7
Intramunicipal		62	20.3
Trip purpose			
Commuting		260	83.6
Others		51	14.4

transport. In other words, in our sample of intermodal e-scooter users, only a 27% of daily e-scooter trips are conducted independently of public transport, revealing intermodal riders' predominant tendency to use the e-scooter as an integrated mode to public transportation more than a stand-alone device.

4.2. Sociodemographic profile and trip purposes of intermodal users

Table 2 presents a breakdown of the participants' characteristics, including gender, age, professional status, level of education, access to vehicles, and place of residency. Key findings include a predominance of male intermodal riders (63%) and a significant representation of younger adults, particularly those aged 18-24 (32.8%) and 25-34 (26%). Most of the sample consisted of employed individuals (82%), with a substantial portion not having access to a personal and motorized vehicle (67.2%). Education levels varied, with a notable number of participants holding secondary education (52.4%), while fewer of them holding university degrees (30.5%). Geographically, participants were distributed across Barcelona (35.4%), its metropolitan areas (RMB 1 and RMB 2), and other regions. Relative to trips, the scale was categorized based on participants reported origins and destinations during the specific trip, revealing the significant intermunicipal nature of the e-scooter intermodality phenomena (79.7% of the participants reported their trip to be start in one municipality and end in another municipality). Additionally, Table 2 explores the trip purposes behind the integration of e-scooters with public transport. Most of respondents (83.6%) utilized e-scooters in combination with public transport for commuting to work or educational institutions, highlighting the e-scooter's role in facilitating essential daily movements. Leisure activities and personal errands are included in *Others*, accounting only for 5.5% and 4.8% of trips, respectively.

4.3. Temporal patterns and satisfaction

Continuing with an examination of trip characteristics, participants reported that a typical intermodal trip involving an e-scooter and public transportation averaged about 52.3 min. However, notable differences emerge when comparing intermunicipal and intramunicipal travelers (Figure 2). In general, intermunicipal travelers reported experiencing longer intermodal trips, with significantly longer public transport stages (Median = 30 min; $\overline{X}$ = 34.2 min) and relatively longer e-scooter stages (Median = 20 min; $\overline{X}$ = 20.8 min) compared with intramunicipal travelers, who declared lower public transport times (Median = 15 min; $\overline{X}$ = 22.3 min) and lower e-scooter times (Median = 15 min; $\overline{X}$ = 19.3 min).

Within the context of these temporal patterns, participants were also asked to rate their satisfaction with both the e-scooter and the public transport stages, on a scale from "0, extremely unsatisfied" to "10, extremely satisfied." Our analysis indicates that, on average, intermodal users of e-scooters and public transport report a high level of satisfaction with their e-scooter stage, scoring it at 7.8 out of 10. In contrast, their opinion on the public transport component yields an average score of 6 out of 10. This disparity in almost 2 points highlights the differential user experience across the two modes of transport and suggests a preference for the e-scooter stage over the public transport stage in their intermodal trips. At this point, notable differences between intermunicipal and intramunicipal travelers are also revealed (Table 3). On the one side, intermunicipal travelers report consistently higher satisfaction with their e-scooter stage, with an overall average score of 8.1, while intramunicipal travelers rate it lower at 6.8. This difference is more pronounced in short stages, where intermunicipal travelers score 8.2 compared to just 6.7 for intramunicipal travelers. In contrast, public transport stage satisfaction shows less variation between the two groups, averaging around 6.1 for intermunicipal and 6.0 for intramunicipal travelers. This analysis uncover gests that the opportunity to ride an e-scooter to and from the public transportation main system especially contributes to increase travel satisfaction for those travelers breaking the municipal boundaries, and that this satisfaction it is unlinked to the amount of time riding the device.

4.4. Intermodality ratio (IR) and predictors of exclusivity

To better understand the factors that influence the integration of e-scooters with public transport in daily mobility, a Generalized Linear Model (GLM) was used to identify key demographic, socioeconomic, and geographic predictors of the IR. The model, presented in Table 4, examines how these factors impact the likelihood of respondents frequently combining e-scooter trips with public transport versus using the e-scooter in more diverse transport scenarios, revealing place of residence as the most significant predictor. Specifically, respondents living in Barcelona ($B = -0.168$, $p = 0.005$) or the 1st metropolitan ring ($B = -0.140$, $p = 0.018$) show significantly lower IRs compared to those living outside these areas. This suggests that individuals in these urban and metropolitan areas are less likely to use e-scooters exclusively in combination with public transport and more likely to use them for other purposes as well. On the other hand, respondents living outside Barcelona's urban influence tend to have higher IR, meaning they are more likely to rely on e-scooters exclusively in combination with public transport. Interestingly, age also emerged as a significant predictor ($B = 0.004$, $p = 0.045$), indicating that for each additional year in age, the likelihood of engaging in intermodal travel involving e-scooters increases slightly. Older individuals are thus more likely to exclusively use e-scooters in combination with public transport compared to younger respondents. Other variables, such as gender, education level, professional status, and vehicle access, did not significantly influence the IR.

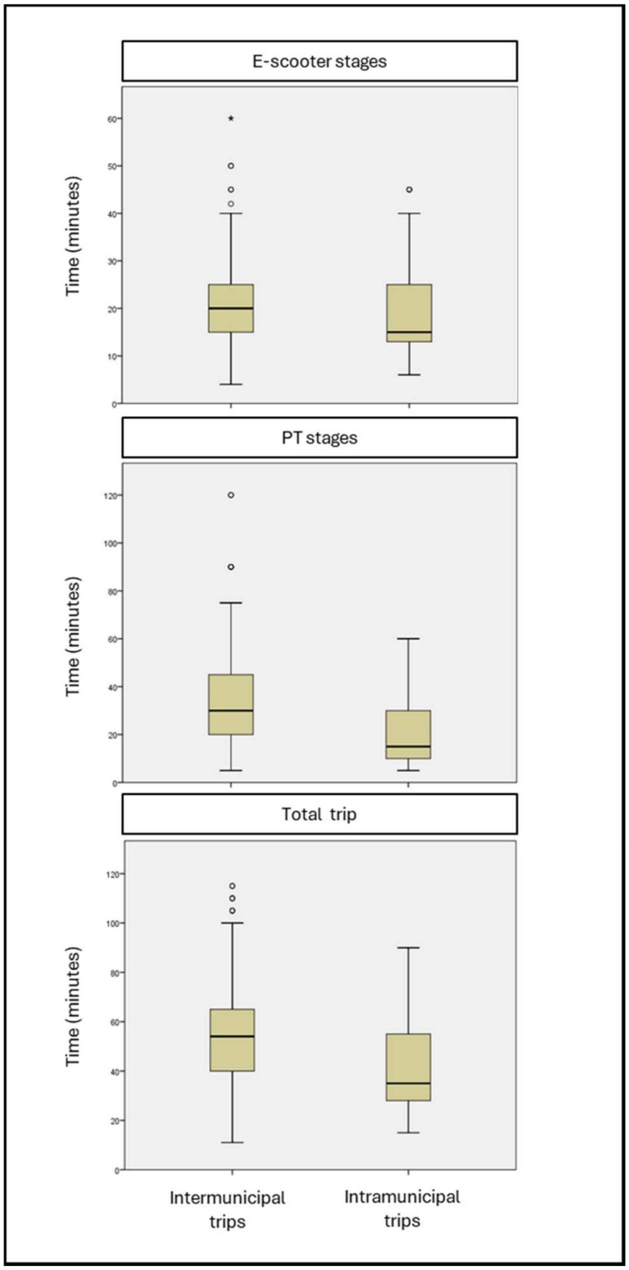

Figure 2. Average time spent on an intermodal e-scooter trip, by scale of the trip and stages.

4.5. Stated behavioral shifts in response to e-scooter prohibition

Finally, building upon the understanding of current intermodal e-scooter usage patterns, we extend our analysis to consider how the forthcoming prohibition of e-scooters on public transport may reshape suburban travelers' mobility. As shown in Figure 3, a notable 32% of intermodal users declared they planned to replace e-scooter segments of their journeys with walking, implying that the affected trips are sufficiently short to transition to pedestrian travel. According to participants' answers, public transport will absorb almost 16% of the former demand for e-scooters. An additional 12% of our participants reported them replacing the e-scooter with another personal mobility device, such as the bike. Interestingly, 12% of participants declared not foreseeing any change in their habits, implying that they would risk being fined if found with an e-scooter during their public transport use. Meanwhile, a smaller group foresees switching to cars (10%), which raises concerns about increased traffic congestion and environmental impacts, contrasting with the intended benefits of micromobility solutions. Among these car adopters, only 16% declared they

Table 3. Average satisfaction scores for e-scooter and public transport stages, by scale of the trip.

	Intermunicipal travelers ($N = 245$)		Intramunicipal travelers ($N = 62$)	
Stage[1,2,3]	E-scooter stage satisfaction ($\bar{X}$)	PT stage satisfaction ($\bar{X}$)	E-scooter stage satisfaction ($\bar{X}$)	PT stage satisfaction ($\bar{X}$)
Short stage	8.2	4.8	6.7	6.7
Medium stage	7.9	6.3	6.3	4.7
Long stage	8.1	5.8	7.8	5.8
Overall	8.1	6.1	6.8	6.0

[1]For e-scooter stages: short (<12.5 min), medium (12.5 - 21 min), and long (>21 min).
[2]For intramunicipal public transport stages: short (<20 min), medium (20- 35 min), and long (>35 min).
[3]For intermunicipal public transport stages: short (<40 min), medium (40- 70 min), and long (>70 min).

Table 4. Parameter estimates for the generalized linear model (GLM) predicting the intermodality ratio (IR).

Exploratory variables	B	Std. error	Lower CI	Upper CI	Wald Chi-square	df	*p*-value
Constant	−0.176	.1422	−0.455	.102	1.539	1	.215
Age	.004	.0024	−0.001	.009	2.968	1	.045
Gender							
Female	.026	.0521	−0.076	.128	.244	1	.622
Level of studies							
University (ref)							
None of primary	−0.020	.0794	−0.175	.136	.062	1	.803
Secondary	.016	.0561	−0.094	.126	.080	1	.777
Professional status							
Student (ref)							
Employed	−0.001	.0800	−0.158	.156	.000	1	.989
Unemployed	−0.351	.1973	−0.737	.036	3.156	1	.076
Access to vehicle							
No (ref)							
Yes. 1	−0.108	.1070	−0.318	.102	1.021	1	.312
Yes. 2	−0.062	.1075	−0.272	.149	.330	1	.566
Place of residency							
Beyond 1st metro ring (ref)							
1st metropolitan ring	−0.140	.0595	−0.257	−0.024	5.563	1	.018
Barcelona	−0.168	.0591	−0.283	−0.052	8.037	1	.005

Notes on the model: Deviance/df = 0.108; Pearson Chi-Square/df = 0.108; Omnibus Test (Likelihood Ratio Chi-Square = 23.903. $p = 0.008$)

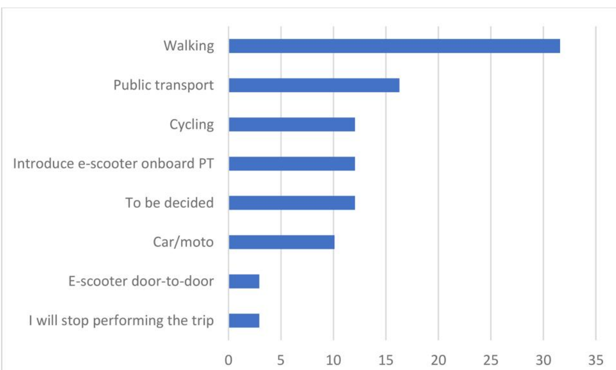

Figure 3. Stated adaptation strategies to the e-scooter ban (% of responses).

would adopt a park-and-ride strategy, parking their car at a public transport station and continuing their trip *via* transit. A 3% of our respondent declared they would perform the full trip using their e-scooter, from door to door, and an additional 3% declared they would stop doing that trip. Lastly, "Not decided" (12%) category indicated a significant degree of uncertainty regarding future travel choices.

Additionally, this final part of the results aims to provide a comprehensive picture of the factors explaining the likelihood of adopting one of these strategies in response to the introduction of the ban, by using a multinomial logistic regression model (Table 5). The primary objective is to understand the characteristics associated with each strategy, with "I will walk to the station" serving as the reference group, as it represented both the most widely reported adaptive strategy by participants and the most universally accessible or democratic strategy to adapt to.

4.5.1. "Public transport" vs "walking"

Being a female increases almost 3 times the odds of reaching the main public transport station by public transport as a result of the introduction of the ban compared with walking to the station.

4.5.2. "Cycling" vs "walking"

Not having access to a private vehicle decreases the odds of cycling to the public transport station as a result of the introduction of the ban compared with walking to the station.

4.5.3. "Introducing the e-sooter onboard" vs "walking"

Being a year older decreases the odds of keeping on introducing the e-scooter onboard no matter the restriction compared with walking to the station. In contrast, those who are not employed are almost 5 times more likely to introduce the e-scooter onboard compared to walking to the station as a result of the introduction of the ban.

4.5.4. "To be decided" vs "walking"

There is no specific sociodemographic characteristic significantly related to the uncertainty of future travel choices as a result of the introduction of the ban.

4.5.5. "Using the car/moto" vs "walking"

Not having access to a private vehicle logically decreases the odds of using a car or a moto to reach the public transport station as a result of the introduction of the ban compared with walking to the station.

4.5.6. "E-scooter door-to-door" vs "walking"

Living in Barcelona increases by 33 the odds of using the e-scooter door-to-door compared to walking to the public transport station as the result of the ban.

4.5.7. "Stop doing the trip" versus "walking"

Those only holding primary education are 13 times more likely to stop doing the trip compared with walking to the station as a result of the ban. Living in Barcelona increases 5 times the odds to stop doing the trip compared with walking to the station as a result of the ban. Additionally,

Table 5. Adjusted associations between the socioeconomic characteristics. locational variables. and stated adaptation strategies to the ban. Multinomial logistic regression model (reference = "I will walk to the station").

		1. Public transport			2. Cycling			3. I will continue introducing the e-scooter on board PT			4. To be decided		
		B (St.err)	OR (Exp)	CI 95%	B (St.err)	OR (Exp)	CI 95%	B (St.err)	OR (Exp)	CI 95%	B (St.err)	OR (Exp)	CI 95%
Intercept		−0.421 (0.814)			−1.123 (0.875)			0.677 (1.093)			−0.161 (0.917)		
Age		−0.022 (0.019)	.979	(0.943; 1.015)	0.007 (0.018)	1.007	(0.972; 1.044)	−0.096 (0.028)	0.909*	(0.860; 0.960)	−0.028 (0.022)	.972	(0.932; 1.014)
Gender (ref = male)	Female	1.026 (0.397)	2.789*	(1.282; 6.068)	0.651 (0.433)	1.917	(0.821; 4.475)	0.283 (0.478)	1.327	(0.520; 3.386)	0.125 (0.466)	1.133	(0.455; 2.823)
Level of studies (ref = University)	Primary	1.063 (0.618)	2.895	(0.863; 9.713)	−0.004 (0.761)	0.996	(0.224; 4.432)	0.607 (0.673)	1.834	(0.490; 6.864)	0.506 (0.637)	1.658	(0.476; 5.776)
	Secondary	0.837 (0.447)	2.309	(0.928; 5.748)	0.479 (0.468)	1.615	(0.645; 4.042)	−0.135 (0.544)	.874	(0.301; 2.539)	0.021 (0.506)	1.022	(0.379; 2.752)
Professional status (ref = Employed)	Other	−0.097 (0.505)	.907	(0.337; 2.442)	−0.020 (0.614)	.980	(0.294; 3.263)	1.516 (0.714)	4.555*	(1.124; 18.459)	−0.037 (0.549)	.963	(0.328; 2.828)
Access to vehicle (ref = Yes)	No access	−0.839 (0.447)	.432	(0.180; 1.039)	−0.972 (0.467)	0.378*	(0.151; 0.944)	−0.781 (0.519)	.458	(0.166; 1.266)	−0.358 (0.519)	.699	(0.253; 1.932)
Place of residency (ref = Metropolis)	Barcelona	0.102 (0.405)	1.108	(0.500; 2.452)	0.183 (0.444)	1.200	(0.503; 2.866)	0.251 (0.463)	1.286	(0.519; 3.183)	0.397 (0.428)	1.487	(0.643; 3.438)
Trip purpose (ref = other)	Work/studies	−0.074 (0.521)	0.928	(0.335; 2.576)	−0.077 (0.596)	0.925	(0.288; 0.977)	−0.802 (0.555)	0.448	(0.151; 1.330)	0.261 (0.607)	1.298	(0.395; 4.268)

		5. Car/moto			6. E-scooter door-to-door			7. I will stop performing this trip		
		B (St.err)	OR (Exp)	CI 95%	B (St.err)	OR (Exp)	CI 95%	B (St.err)	OR (Exp)	CI 95%
Intercept		0.068 (1.097)			−0.417 (2.014)			−5.749 (1.978)		
Age		−0.034 (0.022)	.966	(0.926; 1.008)	−0.047 (0.047)	.954	(0.871; 1.046)	0.019 (0.027)	1.019	(0.966; 1.075)
Gender (ref = male)	Female	0.372 (0.496)	1.451	(0.549; 3.833)	−0.369 (0.974)	.691	(0.103; 4.659)	1.053 (0.764)	2.866	(0.641; 12.812)
Level of studies (ref = University)	Primary	−0.559 (1.152)	0.572	(0.060; 5.468)	−1.396 (1.398)	0.248	(0.016; 3.836)	2.626 (1.274)	13.825*	(1.138; 167.939)
	Secondary	0.566 (0.513)	1.761	(0.645; 4.807)	−2.998 (1.385)	0.050*	(0.003; 0.753)	1.723 (1.163)	5.602	(0.573; 54.764)
Professional status (ref = Employed)	Other	0.716 (0.866)	2.047	(0.375; 11.164)	−2.534 (1.323)	.079	(0.006; 1.062)	0.449 (1.184)	1.566	(0.154; 15.951)
Access to vehicle (ref = Yes)	No access	−2.984 (0.587)	0.051*	(0.016; 0.160)	0.098 (1.252)	1.103	(0.095; 12.836)	−0.489 (0.989)	.613	(0.088; 4.260)
Place of residency (ref = Metropolis)	Barcelona	0.839 (0.504)	2.315	(0.863; 6.211)	3.499 (1.280)	33.091*	(2.695; 406.339)	1.616 (0.774)	5.032*	(1.103; 22.953)
Trip purpose (ref = other)	Work/studies	−0.074 (0.521)	1.082	(0.255; 4.589)	1.686 (1.372)	5.397	(0.367; 79.446)	−1.893 (0.830)	0.151*	(0.030; 0.766)

Pseudo R (Nagelkerke) = 0.353.
*p-value < 0.05; B (S.E.): coefficient (standard error); OR: odds ratio; CI: confidence interval

combining e-scooter and public transport for commuting purposes decreases the odds of stopping performing the trip compared to walking as a result of the introduction of the ban.

5. Discussion

Exploring the usage patterns of intermodal e-scooter users has provided valuable insights into the profile of such a specific group of travelers. As expected, their sociodemographic characteristics remain closely aligned with broader trends observed in other urban contexts -where e-scooter use is predominantly associated with younger, male demographics (Bieliński et al., 2021; Laa & Leth, 2020). However, contradicting Moinse et al. (2024), in Barcelona and its metropolitan region e-scooter as an intermodal device do not appear to be more gender inclusive than e-scooter as a standalone device. At the socioeconomic level, our findings reveal a nuanced influence of certain factors in shaping e-scooter and public transport intermodality. Notably, a significant segment of intermodal e-scooter users in our sample have education levels limited to secondary school, diverging from the higher educational levels observed in other European urban contexts (Jiao & Bai, 2020; Nikiforiadis et al., 2021). This indicates that, at least in the Barcelona context, intermodal e-scooter use may appeal to more economically constrained populations, who view e-scooters as a cost-effective solution for their mobility needs, particularly in accessing public transport. Logically, this also suggests that the ban on bringing e-scooters onto public transport may disproportionately affect lower-educated and potentially more economically disadvantaged groups. The ban thus risks exacerbating existing inequalities in mobility access, disproportionately impacting specific sociodemographic groups and exposing potential socioeconomic disparities.

In addition to these socioeconomic disparities, a key finding from our analysis is the high intermodality ratio observed. Defined as the frequent combination of e-scooters with public transport, relative to a low use of the e-scooter for door-to-door trips, this elevate ratio indicates the strong inclination among this specific group of riders to rely on the device exclusively for transit support rather than as a final, all-encompassing transport solution (i.e., for all types of travel or as the primary mode of transportation). Instead of relying on the device for all type of trips, as suggested by Simma and Axhausen (2001), who argued that ownership typically predisposes individuals to use a specific mode of transportation for a variety of trips and purposes, our findings show that intermodal riders strategically use e-scooters to bridge the gaps to and from public transportation, particularly for work or study-related purposes, which aligns with findings in Moinse et al. (2024) in France. This selective use contrasts with the monomodal patterns observed among urban e-scooter owners in the study by Laa and Leth (2020), for instance, where riders tend to show a greater level of attachment to the their private device for a wider range of purposes. These findings not only highlight the strategic role of e-scooters as connectors to public transport, but also reveals that privately-owned e-scooter users are more than a monolithic group of travelers, underscoring the variability of e-scooter usage based on travel context.

In fact, this differential trend observed in our study compared to analyses focusing primarily on more urban uses of e-scooters is also apparent within our own sample. Despite a predominant tendency among our participants to employ these vehicles only in combination with public transportation, our results reveal that residents living outside Barcelona's urban core are considerably more prone to engage exclusively in e-scooter intermodal practices in their daily strategies (i.e., higher IR). According to our models, those living in more peripheral regional areas seem to only rely on e-scooters to bridge gaps in public transport accessibility. For them, the device is basically a tool that helps mitigate the system's rigidity, as previously suggested by Oostendorp and Gebhardt (2018), by offering a solution to overcome first- and last-mile challenges, thereby improving accessibility and overall transport efficiency. On the other hand, besides using the e-scooter to reach public transport installations, our results show that Barcelona's residents are more prone to also use e-scooters for a broader spectrum of their transportation needs, indicating a device's higher intensity of use, finding which aligns with previous results in Roig-Costa, Marquet, et al. (2024). A logical explanation for this homogenous behavior of monomodal e-scooter users in urban areas, as opposed to more rural areas has to do with the average travel distances (variable not included in this study), which would be higher, on average, in rural than in urban areas, or simply in safety reasons, as previously noted by Le Boennec and Salladarré (2023). In compact cities like Barcelona, the lightweight and maneurable characteristics of e-scooters, along with their sufficient autonomy, make door-to-door trips more feasible compared to suburban or sprawled contexts. This level of attachment to the device is further reflected in travelers stated adaptive strategies to the ban, in which urban residents show significantly higher likelihoods of using e-scooter as an alternative to travel door-to-door. Therefore, despite the introduction of the restrictive policy pretends the rationalization of e-scooter usage, our results show that when travelers are subjected to specific spatial conditions this might reinforce its usage, translating into a complete substitution of public transport (Wang et al., 2023).

A closer examination reveals that not only urban travelers but also younger individuals are most prone to developing broad daily mobility strategies exclusively centered around private e-scooter usage (i.e., lower IR). According to our model, young riders incorporate the e-scooter as a standalone mode of transport throughout the day, beyond simply using it in trips involving public transport. This behavior contrasts with patterns shown by older segments of the population, who tend to rely on e-scooter exclusively in combination with public transport. This trend is concerning, as it suggests a shift away from context-dependent, multimodal, and more rational mobility strategies toward more monomodal and irrational patterns. Such a shift may be particularly significant or worrisome during youth, a stage of life when travel habits are being formed, potentially shaping long-term mobility choices (Schwanen et al., 2012). While it is true that owning an e-scooter provides younger individuals with a flexible option, it accustoms them to heavily rely on a single mode of transport. As demonstrated by Rejeb et al. (2023), selecting a mode of transport driven by an automatic decision-making process can potentially limit riders' engagement with alternative or context-appropriate mobility options, which compromises the sustainability of the system.

So far, however, it is unclear whether what younger riders are most attached to is the e-scooter itself or the convenience of monomodal travel. Nonetheless, this attachment to monomodal behavior could set a precedent for future unsustainable mobility patterns, as previously seen with motorbike or car drivers who become heavily reliant on a single mode of transportation (Marquet & Miralles-Guasch, 2016). In fact, the development of an incoming irrational relationship with the device can be already inferred from participants' stated adaptive responses to the ban, with younger users being significantly overrepresented among those expecting noncompliance to the rule and willing to make no changes in their behavior. This high tendency for rule-breaking behavior among young riders in e-scooter ridership contexts aligns with existing research in Paris (Gioldasis et al., 2021). While this could indicate a misunderstanding of the legal risks involved, it also highlights the importance of considering age as a factor that may explain different behavioral responses to technological innovations and changeable legal frameworks (Flores & Jansson, 2021). Over time, these ingrained habits could reduce the likelihood that younger riders will transition to more diverse or sustainable travel behaviors as they age, raising concerns about the long-term implications for sustainable or even safe urban mobility.

Additionally, the above-mentioned predominant reliance on e-scooters in combination with public transport for occupational reasons reveals the significant societal implications of imposing bans on their use. Commuting for work or study, especially in face-to-face roles and technical jobs, is inherently inflexible, constrained by strict schedules and location demands, unlike the more adaptable nature of leisure or errand trips (Stein et al., 2022). This inflexibility in working purposes is corroborated by our model, where intermodal e-scooter users traveling for occupational purposes appear to be the least likely to stop performing the trip as a result of the introduction of the ban. Although it is important to note that these conclusions are derived from our specific sample, such a prohibition on e-scooters within public transport systems would not only extend commuting times to specific populations, but also disrupt their daily routines and reduce their access to essential services, thereby adversely affecting their quality of life (Lucas, 2012). In fact, an even more worrisome effect the introduction of the ban could have, according to our model, is the exclusion from the labor market of specific groups of population, especially those less educated, due to the disproportionate costs resulting from the introduction of the ban, which further compromises the social sustainability of the policy. Related to that, on the other side of the coin, the fact that those who reside in Barcelona are the ones also most prone to stopping the trip as a result of the regulation could be connected with urban dwellers' higher options to work from home than equivalent metropolitan residents, trend which aligns with previous findings in the United States (Paul, 2022).

In fact, related to that, the analysis of temporal patterns and satisfaction levels reveals that particularly intermunicipal travelers are those more likely to experience a marked decrease in overall travel satisfaction due to the ban. These metropolitan travelers report the highest levels of satisfaction with the e-scooter stages, regardless of the duration of the stage (whether it is short, medium, or long), which underscores the importance of e-scooters in enhancing their overall travel experience. Their consistently higher satisfaction scores associated with e-scooter stages, compared not only to their public transport phases, but also with the e-scooter stages' satisfaction levels declared by intramunicipal travelers, highlight the convenience and efficiency that e-scooters bring specifically to the commuting routines of regional travelers. This expected reduction in travel satisfaction—a key element of individuals' subjective well-being (Choi et al., 2013)—underlines the significant repercussions of the ban in terms of travel time, but also in terms to broader quality of daily life, as it leaves unmet the needs of those who have come to rely on the benefits provided by e-scooters in their commuting routines. This becomes especially relevant for metropolitan travelers, for whom the combination of e-scooters and public transport seems to be more critical.

However, despite the fact that the prohibition effectively narrows the diversity of mobility options available to intermodal travelers, it may not result in a significant negative environmental impact in the short-term. Contrary to the widespread assumption that users would switch to car use if e-scooters were banned from public transport, our results reveal that most intermodal users will in fact return to their prior transportation habits and that concerns about a possible increase in car usage, which could exacerbate congestion and undermine sustainability goals associated with micromobility (Nikiforiadis et al., 2021), would not apply in this scenario. In fact, the relatively small portion of respondents who indicated a switch back to car/moto (10%) perfectly fits with previous replacement schemes already observed in dense and compact European contexts, where shifts to e-scooter use primarily replaced active and public transportation modes (Bieliński et al., 2021; Roig-Costa, Marquet, et al., 2024). According to our models, however, users being "pushed" back into car dependency will not only step back from e-scooter usage, but also from public transport dynamics. Options like park-and-ride, for instance, can only address the first mile of a trip, but fail to solve the last mile challenge. Having got used to a device providing a unique level of convenience that is difficult to replicate with other modes of transport (Litman, 2021), instead of only reaching the public transport station by car, a huge majority of car adopters anticipate completing the full entire trip by car, erasing public transport modes from their commuting mobility strategies.

6. Conclusions

Our study has analyzed the intermodal dynamics of e-scooter usage in the Barcelona region and assessed the potential impacts of a ban on e-scooters in public transportation. Results indicate that intermodal e-scooter then to be young, employed men. However, unlike in other urban contexts, those engaging in intermodal e-scooter usage tend to have lower socioeconomic backgrounds, a finding that reinforces prior results in the region. Moreover, age and, particularly, place of residence significantly influence the likelihood of intermodal individuals choosing to use e-scooters also as a standalone device, finding that might be uncovering a clear division on the role e-scooters play in the mobility strategies of users at different urban and suburban territorial levels.

The analysis reveals a worrisome outcome: banning e-scooters from public transport could significantly disrupt vital travel routines, likely resulting in longer commute times and reduced access to essential services. Such disruptions are expected to lower travel satisfaction considerably, negatively impacting users' quality of life. However, although the ban might limit mobility choices for intermodal users, it may not have a substantial environmental impact. Both the stated replacement preferences, with only 10% of participants indicating they would substitute the now-banned e-scooter trip with a car trip, combined with trends identified in previous research showing that e-scooter users primarily replace active modes of transport (Roig-Costa, Miralles-Guasch, et al., 2024), suggest that the ban is unlikely to result in a substantial net increase in emissions. On the contrary, it is likely that the ban will lead to a decline in travel quality and trip satisfaction among affected individuals, who are expected to revert to their previous travel habits that existed before the introduction of the e-scooter. We should note, however, that our study was designed to capture stated preferences responses to an announced but not yet implemented policy ban. Future research should thus analyze the actual choices made by riders after the policy ban was finally implemented, thereby informing of the real impact of policy making in urban and suburban mobility.

This study is not without limitations, as the adoption of a non-probabilistic sampling method, coupled with a random intercept approach, constrains our capacity to generalize our conclusions to the broader City of Barcelona and its regional area and might limit the scope of our findings. However, considering the significant role e-scooters play in daily commuting, particularly for employment-related travel, this limitation should not limit our capacity to incur in policy recommendation to, at least, soften the social impact of the ban. This disruption highlights the need for mobility policies that take into account the essential role of e-scooters in the commuting ecosystem, betting for approaches beyond outright bans to ensure the sustainability of urban transport systems without compromising the well-being of their users. Given the different mobility needs between urban cores and metropolitan areas, policies might need to apply differently across these contexts. For example, in metropolitan public transport systems, restrictions could be more flexible, while urban networks might require more stringent measures.

Introducing special time windows during peak commuting hours to accommodate e-scooters within public transportation networks would leverage the commuting potential of e-scooters by facilitating a seamless and efficient intermodal connection for commuters. In addition, promoting the integration of e-scooters with public transport systems through the establishment of dedicated parking and sharing facilities at transit hubs can further enhance the accessibility and efficiency of public transportation. Importantly, these policy recommendations are grounded in understanding the stated preferences and intended behaviors surrounding e-scooter use. Therefore, continuous monitoring and research are essential to evaluate the real-world impacts of these policies commuting patterns in both urban and metropolitan areas.

Disclosure statement

The authors report there are no competing interests to declare.

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