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Gendered travel behaviour in micromobility? Travel speed and route choice through the lens of intersecting identities

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ABSTRACT

Evidence shows that the use of micromobility vehicles is currently skewed towards young men, who are more likely to adopt risky behaviours, such as fast or aggressive riding. However, research on micromobility travel behaviour founded on GPS data has repeatedly failed to disaggregate findings by gender, or to account for intertwined sociodemographic identities. In this study, we investigate how bike-share cyclists and private e-scooter riders navigate through Barcelona's cycling facilities, and whether intersecting identities (in terms of gender, age and parenthood) influence their performance. Using 911 GPS-tracked trips of 89 participants, we build a multilevel linear mixed effects model that analyses the speed at which cyclists and e-scooter riders travel. The results show that the speed gender gap is particularly salient among e-scooter users, while being almost non-existent among cyclists. The model further indicates that cycling facilities influence riding speed, and that intersecting identities significantly explain how micromobility users circulate through the city. Drawing on theories of performativity and embodiment, we argue that findings pointing to gender differences in travel behaviour might be explained by women's unwillingness to negotiate traffic or tolerate harassment in highly masculinised spaces. These findings contribute to the limited available knowledge on the objective travel behaviour of micromobility users from a gender and intersectional perspective, i.e. recognising the complex way in which multiple forms of discrimination associated with identity combine. We also provide valuable insights into how the design of urban environments and targeted policies can have diverse effects on different micromobility users.

1. Introduction

The emergence of micromobility is changing mobility dynamics in cities worldwide while adding complexity and creating new challenges. A myriad of conventional and electric bicycles, electric scooters (e-scooters hereafter), and other light personal mobility vehicles weave their way through lanes, roads, and footpaths, blurring the traditional boundaries of transport spaces (Gibson et al., 2022). Nevertheless, the rise of micromobility as a new competitor for urban space has created significant friction with drivers and pedestrians alike. Micromobility users must continually negotiate their right to public space on roads and sidewalks, a negotiation that can lead to conflicts for urban space (Essa et al., 2018; Liang et al., 2021). When cyclists and e-scooter riders are asked to share the space with cars they often feel insecure and disregarded by drivers (Egan and Philbin, 2021; Levels, 2020). When asked to share the space with pedestrians, they all need to learn how to interact with each other, since the faster pace of bicycles and e-scooters threatens walkers' perception of safety (Che et al., 2021; Tuncer et al., 2020). While such conflicts are inherent to the nature of public space, they are highly dependent on how these new forms of transportation are manoeuvred (Gibson et al., 2022).

Conflicts for urban space also need to be framed in terms of gender. Men on two wheels are more likely to perform risky behaviours, such as stunts, fast riding, swerving, quickly accelerating or braking or running red lights (Arellano and Fang, 2019; Balkmar, 2018; Gioldasis et al., 2021; Saber et al., 2022). In Barcelona, men cyclists are not only more prone to breach traffic rules (Lind et al., 2021), but they also constitute the majority of micromobility users (Roig-Costa et al., 2021). Apart from

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modal choice and riding behaviour, gender also influences route preferences. In this respect, women seem more reluctant to ride through off-street lanes and paths shared with cars (Fitch and Handy, 2020; Graystone et al., 2022). Hence, urban space conflicts are not only drawn as unbalanced power dynamics between vehicles with different speeds but also as conflicts in which there is an uneven share of riders in terms of gender, manoeuvring and using the space differently. These underlying gendered processes of space conflicts have implications for urban policy. Therefore, studying the relations between riding behaviour, route preferences and gender is fundamental to design inclusive spaces that can ease conflicts between drivers, micromobility users, and pedestrians. To date, only a few studies have approached riding behaviour and route choice of micromobility users from a gender perspective using objective data.

This study was set in Barcelona, where micromobility trips represent 3.9% of the modal share (IERMB, 2020). We investigate how bike-share users (21% of micromobility share) and private e-scooter users (26% of micromobility share) navigate the public space, and whether intersecting identities in terms of gender, age and parenthood influence their travel behaviour and performance. To operationalize riding behaviour we analyse the speed, cycling infrastructure preferences, frequency of use, time of the day and distance travelled using the GPS-tracked trips of 89 private e-scooter and bike-share users during 283 days. We hypothesise that (1) intersecting identities influence trip characteristics and spatiotemporal preferences and that (2) the outcome is different from the one expected from the simple accumulation of single identities. Drawing on the theory of intersectionality (Crenshaw, 1991), we expect that forms of oppression combine and overlap creating travel patterns that are distinct from those expected if unidimensional identities were considered. In this article, we consider the age, gender and child-care responsibilities of participants to holistically understand their experience riding bicycles and e-scooters.

Following this introduction, we contextualise how intersecting identities shape the riding experience, and how this diversity has been regarded when constructing speed models. Next, we describe how GPS data were map-matched to the street network and how routes were inferred. The following sections explore the scheduling of trips, built environment preferences, and speed of micromobility. To conclude, we discuss the intertwined nature of cyclists' and e-scooter riders' travel behaviour with sociodemographic variables, and the resulting implications in urban policies.

2. Literature review

Previous literature on micromobility has acknowledged a gender gap, in which women are less likely to travel with micromobility modes than men (Laa and Leth, 2020; Pellicer-Chenoll et al., 2021; Reilly et al., 2020; Sardi et al., 2019). This gender split is more noticeable for e-scooter riders than for cyclists (Bieliński and Ważna, 2020), a finding also observed in Barcelona, where women represent a third of e-scooter riders and, almost half of bike-sharing cyclists (Roig-Costa et al., 2021). Indeed, gender differences in cycling appear to be linked to the presence of dedicated cycling facilities (Higuera-Mendieta et al., 2021; Wang and Akar, 2019). Thus, bicycle use is close to gender parity in contexts with extensive cycling infrastructure, while the gender gap is broader in those places where dedicated infrastructure is missing (Braun et al., 2016; Mooney et al., 2019). Nonetheless, gender is not the only sociodemographic factor to influence cycling and riding rates (Bretones and Marquet, 2022). When micromobility use is studied through intersecting identities, researchers have found that it tends to be skewed towards young, employed, highly educated, white men without children (Dill and McNeil, 2020; Reck and Axhausen, 2021; Soltani et al., 2019; Xin et al., 2018). These social differences in micromobility use permeate at all levels, from travel behaviour indicators such as the number of trips, distance travelled or trip purpose, to riding performance such as speed, acceleration, or aggressiveness.

Social differences determine not only the decision to choose micromobility modes but also the riding behaviour during the trip. In this respect, men are less prone to rule compliance, as well as more likely to adopt risky and fast riding practices (Arellano and Fang, 2019; Flügel et al., 2019; Gioldasis et al., 2021; Lind et al., 2021; Romanillos and Gutiérrez, 2020). These differences in travel behaviour have been traditionally attributed to a general attitude of risk aversion by women (Graystone et al., 2022; Prati et al., 2019). However, the dichotomous conceptualisation of gender picturing men as fast riders and women as safety concerned fails to capture the gendered processes supporting these differences. As some authors have recently emphasised, the theory of performativity (i.e. how gender is socially constructed) and the theory of embodiment (i.e. the way in which power dynamics influence mobility at the scale of the body) can deepen our understanding of this matter (Ravensbergen et al., 2019).

In the case of cyclists, fast riding has long been associated with an embodied performance of normative masculinity and assertions of spatial dominance (Popan, 2019), that some authors refer to as 'careless masculinity' (Balkmar, 2018). When facing such attitudes, women cyclists have been found to adopt two types of strategies: (1) desisting to compete for their right to occupy the bicycle lane by changing their riding schedules/routes or (2) mirroring fast riding practices (Heim LaFrombois, 2019; Sersli et al., 2022). On the one hand, women reported 'feeling in the way' when encountering aggressive male riding behaviours in the bicycle lane (Sersli et al., 2022). This feeling is rooted in the idea that public spaces have historically been framed as masculine, productive spaces, and women are socialised to perceive that they should not be in them, or if they are then they should minimise their presence whenever possible (Heim LaFrombois, 2019; Sayagh and Dusong, 2021). On the other hand, the second response to fast riding is that women often feel pressured to cycle more rapidly, thus reproducing masculine gender stereotypes (Heim LaFrombois, 2019; Sersli et al., 2022).

In addition to negotiating their presence in the public space, women using micromobility also face the potential negative consequences of increased visibility while riding. Increased visibility is perceived to intensify harassment against women, and the same is stated when gender intersects with other identities, such as race (Balkmar, 2018; Lubitow et al., 2019; Ravensbergen, 2022). Having to deal with increased visibility and the prospect of harassment has a direct effect on the spatial behaviour of women using micromobility, as they develop specific strategies such as avoiding isolated or low-density urban spaces during night-time hours (Pellicer-Chenoll et al., 2021; Sersli et al., 2022). People with other identities also develop specific strategies with which to manoeuvre through the city. For instance, most parents acknowledge changing their behaviour when carrying children on their bicycles by riding more slowly or avoiding busy roads (Hatfield et al., 2019). Likewise, people of colour reported that concerns about police violence and unfair law enforcement treatment constrain their route schedules and choices (Lubitow et al., 2019).

Studies analysing cyclists' and e-scooter riders' gendered performance have used a variety of data sources, such as surveys, interviews and videos (Essa et al., 2018; Gibson et al., 2022; Liang et al., 2021; Tuncer et al., 2020). While each of these methodologies brings a specific set of strengths and weaknesses, the use of GPS-tracked trips is particularly appropriate to understand how micromobility users navigate the public space. GPS devices log precise locations at regular intervals, enabling researchers to derive riding behaviour indicators such as speed, acceleration, and route choice. Most importantly, GPS devices also allow tracks to be associated with GIS context data on the characteristics of the road or infrastructure. This is relevant, as elements of the built environment such as slope, presence of cycling facilities, or density of intersections are known to influence riding behaviour (Almannaa et al., 2021; Eriksson et al., 2019; Zuniga-Garcia et al., 2021). Notwithstanding, riding behaviour does not depend solely on the characteristics of the infrastructure as sociodemographic variables have also been found to be meaningful (Clarry et al., 2019; Hatfield et al., 2019; Lubitow et al., 2019; Romanillos and Gutiérrez, 2020). Despite this, most studies to date have failed to disaggregate data by gender, or only have a small sample size of people who do not identify as men (Eriksson et al., 2019; Li et al., 2020; Zuniga-Garcia et al., 2021). Similarly, the few speed models that include multiple sociodemographic variables, analyse them independently rather than intertwined (Romanillos and Gutiérrez, 2020; Xu et al., 2015). Moreover, speed models have been frequently drawn from smartphone apps that track micromobility trips, such as Strava, Map My Ride, Bikemap or Endomondo. Indeed, most of the studies aimed at analysing speed patterns have used smartphone apps as the main data source: Clarry et al. (2019) explored 5713 trips made by 554 cyclists, Flügel et al. (2019) investigated 48,633 cycling trips undertaken by 328 (e-)cyclists and Romanillos and Gutiérrez (2020) examined 6022 routes uploaded by 328 cyclists. The representativeness of tracking apps users has largely been questioned, not only because they mainly identify as men, but also because these apps exacerbate normatively masculine cycling behaviour (Barrie et al., 2019; Garber et al., 2019; Schirck-Matthews et al., 2021).

3. Methodology

3.1. Study setting

This study was set in the municipality of Barcelona, which is located on the northwest coast of the Mediterranean Sea, and housing 1,636,732 residents (2020). The city has a compact planning organisation and an even spatial distribution of services and amenities. (Marquet and Miralles-Guasch, 2018). Barcelona is equipped with over 200 km of cycling infrastructure divided into bicycle lanes, bicycle sharrows and pedestrianised streets (Fig. 1). Bicycle lanes are physically separated from motorised traffic and pedestrians, in contrast with bicycle sharrows and pedestrianised streets. Bicycle sharrows (a portmanteau of 'shared' and 'arrow') are one-way streets where riders share the driveway with motorised vehicles while pedestrians circulate on the sidewalk. By contrast, the pavement is shared with both pedestrians and motorised vehicles in pedestrianised streets. These streets are usually located in areas with high pedestrian flows, and micromobility vehicles can usually be ridden both ways while motorised vehicles circulate one way with a maximum speed set to 10 or 30 km/h.

Bicycles and e-scooters represent up to 4% of all the trips conducted in the city, and the number of cyclists and riders has grown by 14% since 2018 (Felipe-Falgas et al., 2022; IERMB, 2020) together with an expanding fleet of food delivery workers that travel through the cycling infrastructure (Alvarez-Palau et al., 2021). We narrowed our analysis to conventional (non-electric) bicycles of the public bike-sharing system as well as private e-scooters. The dock-based bicycle sharing system, *Bicing*, has >100,000 registered users and holds a fleet of 7000 vehicles (Soriguera and Jiménez-Meroño, 2020). The membership has an annual cost of €50 and offers unlimited free-of-charge trips for journeys shorter than 30 min. Each additional 30 min of use has a fee of €0.7 and trips longer than 2 h are charged €5/h (Bustamante et al., 2022). In contrast, the municipality does not currently offer an e-scooter-sharing platform nor does it allow private e-scooter enterprises to operate within the city limits. Thus, all current e-scooter users in Barcelona ride their privately owned vehicles.

3.2. Data gathering

Between September 2020 and July 2021, the NEWMOB project

Fig. 1. Cycling infrastructure typologies within the study context. Source: Own elaboration.

surveyed 902 micromobility users in Barcelona streets. Within this operation, a total of 326 e-scooter owners, 251 moto-sharing drivers and 325 bike-sharing users were interviewed using an intercept survey and following the CAPI (Computer Assisted Personal Interviewing) methodology (more information is available in the study by Roig-Costa et al., 2021). Of all the interviewees, a sample of 70 conventional bike-sharing cyclists and 65 e-scooter riders was further asked to wear a GPS device (QStartz BT-Q1000XT; QStarz International Co., Ltd., Taiwan, R.O.C.) for a week. We invited participants to wear the devices all day long except when sleeping. At the end of the study, participants received a 20-trip ticket for the city's public transport. To characterise daily mobility patterns rather than single trips, we excluded those participants who had not worn the GPS a minimum of 8 h in 1 of the 7 days they were given the device. That resulted in a sample of 93 valid users.

3.3. GPS data and travel log

GPS devices were programmed to log the exact location of the participant every 15 s. Afterwards, GPS data were processed through the Human Activity Behavior Identification Tool and data Unification System (HABITUS) software. HABITUS uses a heuristic algorithm to identify trips within GPS trajectories and infer their transport mode by calculating the distance and speed between sequential GPS points (Berjisian and Bigazzi, 2022). Therefore, this software classifies trips with a 90th percentile speed of ≥10 km/h and < 25 km/h as micromobility trips. Trips with a 90th percentile speed below or above the aforementioned speed threshold were respectively classified as walking and driving. These parameters have been used in previous research to successfully distinguish micromobility journeys from walking or motorised trips (Carlson et al., 2015). Given the scope of the research, we filtered out walking and driving trips from the analysis.

HABITUS does not discern between e-scooter and bicycle trips, hence a travel diary was designed to assist in the task of identifying the specific mode of each micromobility trip. Participants were asked to fill out a travel diary at the end of each participated day, requiring them to input daily information on the timing, travel mode, and purpose of individual trips. To avoid human errors associated with travel diaries, such as incomplete entries or misreported time stamps (Kang et al., 2018), we filtered out those participants who combined e-scooter and bicycle trips in a single day ($n = 4$). None of the participants used different travel modes in different days. Consequently, the remaining users ($n = 89$) were either cyclists or e-scooter-riders.

3.4. GIS processing

To analyse how cyclists and e-scooter riders navigate in the public space, GPS tracks were map-matched. GPS points were snapped to the street network using a dynamic buffer with an initial search tolerance of 25 m. If the process failed, the search radius was gradually expanded by an interval of 25 m with the upper tolerance radius set to 150 m. In comparison with other studies, we have used a more constrained search radius to avoid inaccuracies in the route generation process (Li et al., 2020; Romanillos and Gutiérrez, 2020). As a result, 70.4% of GPS points were map-matched with a search radius set to 50 m; 98.0%, with a 100 m radius and 99.4%, with a 150 m radius. Routes were then created employing the Network Analysis toolset from ArcGIS Pro, which uses Dijkstra's algorithm to estimate the shortest path between consecutive points. To remove noisy data trips that either (1) lasted <2 min or >2 h ($n = 234$), (2) whose average speed was >60 km/h ($n = 3$), or (3) that contained unmatched points to the street network ($n = 7$) were filtered out from the analysis (Clarry et al., 2019). Similarly, trips with observations above 60 km/h ($n = 98$) were also excluded (Flügel et al., 2019). As result, 27.3% of generated routes were excluded during the data cleaning process. The number of routes there were in each network segment is captured in 'Appendix A Supplementary material'.

3.5. Sample characteristics and statistical analysis

The final data set used to study the performance of cyclists and riders consisted of 35,538 GPS data points that belonged to 911 trips which were undertaken on 283 different days by 55 unique cyclists and 34 unique e-scooter riders. In this sample, most participants identified as men (56%), were younger than 35 years of age (62%), graduated (58%), employed (79%) and childless (76%). In comparison to Barcelona's population, young adults and men were overrepresented in our sample, although participants shared similar levels of education and employment with the rest of the citizens (Ajuntament de Barcelona, 2022; Idescat, 2021, Idescat, 2021b). The survey handled out to micromobility users offered multiple options to reflect their demographic diversity, particularly regarding gender identity (woman, man, non-binary). Nonetheless, all the participants ended up choosing one of the first two options, and the analysis on gender therefore only evaluated individuals who self-identified as women or men. Each user participated for an average of 3.2 days (sd = 1.7) and 10.2 trips (sd = 8.8) over the week they were given the GPS device.

We used descriptive statistics and bivariate analysis to characterise trip attributes and cycling infrastructure use. Thanks to the map-matching process, we were able to calculate the average speed at each street segment (Fig. 2). Moreover, a multilevel linear mixed effects model was run, modelling the speed of cyclists and e-scooter riders as the sum of urban attributes, sociodemographic characteristics, and temporal variables. Specifically, speed was adjusted by travel mode (bicycle; e-scooter), sociodemographic variables (self-reported gender; age; having a child under 18 years), time variables (type of day; time of day), as well as road characteristics (net route slope; cycling infrastructure typology; traffic lights within 20 m from the observation, intersections within 35 m from the observation). We chose the same distance to traffic lights and intersections as Clarry et al. (2019) to estimate the effect of these urban elements. To test whether travel behaviour was gendered and whether intertwined identities (considering gender, age and parenthood) moderated the riding and cycling speed, we intersected sociodemographic variables within them and with the use of cycling facilities, as well as the time of day. The model, which was built using the R package 'lme4' (Bates et al., 2015), included user-specific and trip-specific random effects to control for unobserved heterogeneity. To facilitate the interpretation of the model, we computed and plotted the marginal effects employing the 'ggeffects' R package (Lüdecke, 2018). We only calculated the marginal effects of those variables that tested for statistical significance at a 95% level of confidence in the model's analysis of variance. The outcome of this process is the predicted speed for each factor's category holding the rest of the variables at their average value.

4. Results

4.1. Trip characteristics

Cyclists and e-scooter riders present distinct travel patterns when navigating public space. Bicycle trips of users of Barcelona's bike-sharing system last significantly longer (2:32 min difference), cover a greater distance (0.7 km difference) and are less frequent (0.5 daily trips difference) than trips made using privately-owned e-scooters (Table 1). Regarding how gender might influence cyclists' and e-scooter riders' performance, the descriptive results indicate that women spend more time travelling and undertake longer trips than men (30 s and 0.4 km difference for cyclists; 26 s and 0.1 km for e-scooter riders). Both micromobility vehicles use the cycling infrastructure quite similarly. Almost half of all bike-share and private e-scooter trips take place using bicycle lanes (44.2%; 42.9%) and the second most used environment is pedestrianised streets (20.1%; 23.6%). It is noteworthy that bicycle lanes and pedestrianised streets are found in 14.6% and 27.8% of Barcelona streets, respectively. The main difference between the two

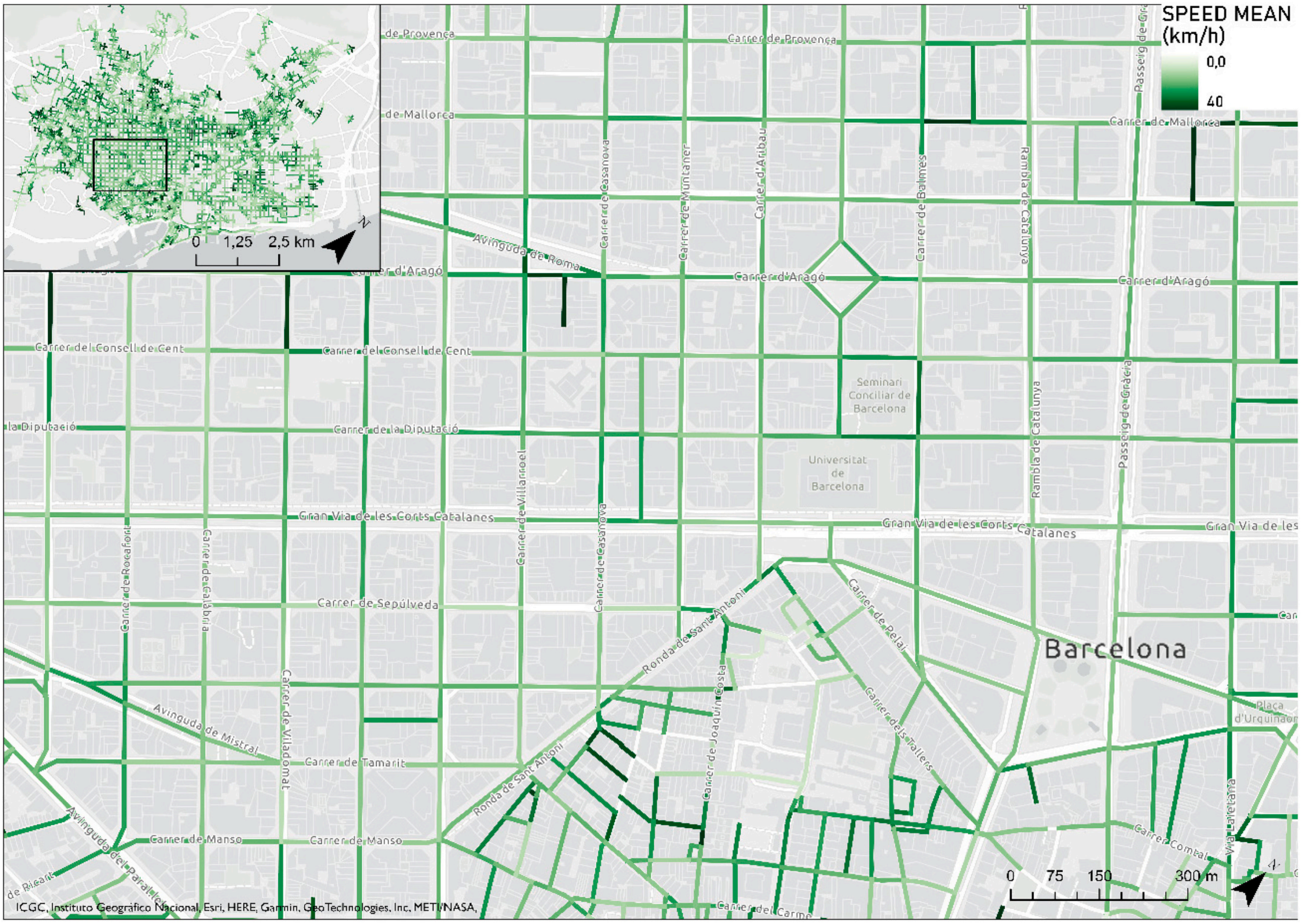

Fig. 2. Average speed on each street network link. Source: Own elaboration.

Table 1
Trip characteristics by transport mode, gender and cycling infrastructure.

		Time in min (sd)	Distance in km (sd)	N of daily trips (sd)	Cycling infrastructure use as % of trip occurring within (sd)			
					Bicycle lane	Bicycle sharrow	Pedestrianised street	None
Shared bicycle	Women	11:06 (8:52)*	3.0 (3.2)*	2.9 (1.9)*	44.8 (31.5)	10.2 (15.4)	17.4 (27.2)	27.5 (28.2)*
	Men	10:36 (7:59)*	2.6 (2.7)*	3.0 (1.9)*	43.7 (32.2)	12.8 (20.3)	22.1 (33.3)	21.4 (26.5)*
	Total	10:48 (8:22)**	2.8 (2.9)**	3.0 (1.9)**	44.2 (31.9)	11.7 (18.4)	20.1 (30.9)	24.0 (27.4)
Private e-scooter	Women	8:59 (7:00)*	2.1 (2.1)*	3.9 (2.6)*	46.1 (33.5)	12.2 (21.5)	23.9 (33.6)	17.8 (21.6)*
	Men	8:08 (6:46)*	2.0 (2.6)*	3.1 (2.6)*	39.5 (32.6)	13.9 (20.6)	23.3 (33.2)	23.3 (27.2)*
	Total	8:34 (6:54)**	2.1 (2.4)**	3.5 (2.6)**	42.9 (33.2)	13.0 (21.1)	23.6 (33.4)	20.5 (24.6)

* Significant *p*-values (<0,05) in the ANOVA test between gender within each transport mode.
** Significant *p*-values (<0,05) in the ANOVA test between transport modes.

vehicles is that e-scooter riders seem less likely to choose streets without any adapted infrastructure: only 20.5% of e-scooter trips take place in unprotected streets, compared to 24.0% of bike-share trips. Results also indicate that route choice between men and women is unequal. Up to 27.5% of all bicycle trips undertaken by women occur within streets with no bike infrastructure whatsoever, whereas men tend to prefer bicycle sharrows (2.6% difference) and pedestrianised streets more often (4.7% difference). In contrast, women riding an e-scooter opt for bicycle lanes (6.6% difference) in greater proportions than men.

In terms of timing, bicycle and e-scooter trips share overall mobility rush hours, although their occurrence during the day is slightly delayed. Fig. 3 compares our micromobility data set to the annual travel survey that interviews a representative sample of residents of the Barcelona Metropolitan Region to study their daily mobility habits and attitudes towards mobility (IERMB, 2020). On weekdays, the volume of trips taken in Barcelona (accounting for active mobility, public transport, and private transport) spikes at 8:00 and 11:00, and reaches its peak around 18:00. Similarly, micromobility usage has its first peak at 9:00 and reaches its summit at 13:00–14:00 and 18:00–19:00. In contrast to e-scooter travels, bike-share trips have an additional peak hour around 16:00. There is an even number of women and men cycling during the daytime. Nonetheless, most of the bike-share trips taken from 18:00 until midnight are made by men. For e-scooters, men's use peaks at 11:00 and 21:00, while women's spikes are closer in time. Indeed, women represent most of the e-scooter users during the afternoon valley.

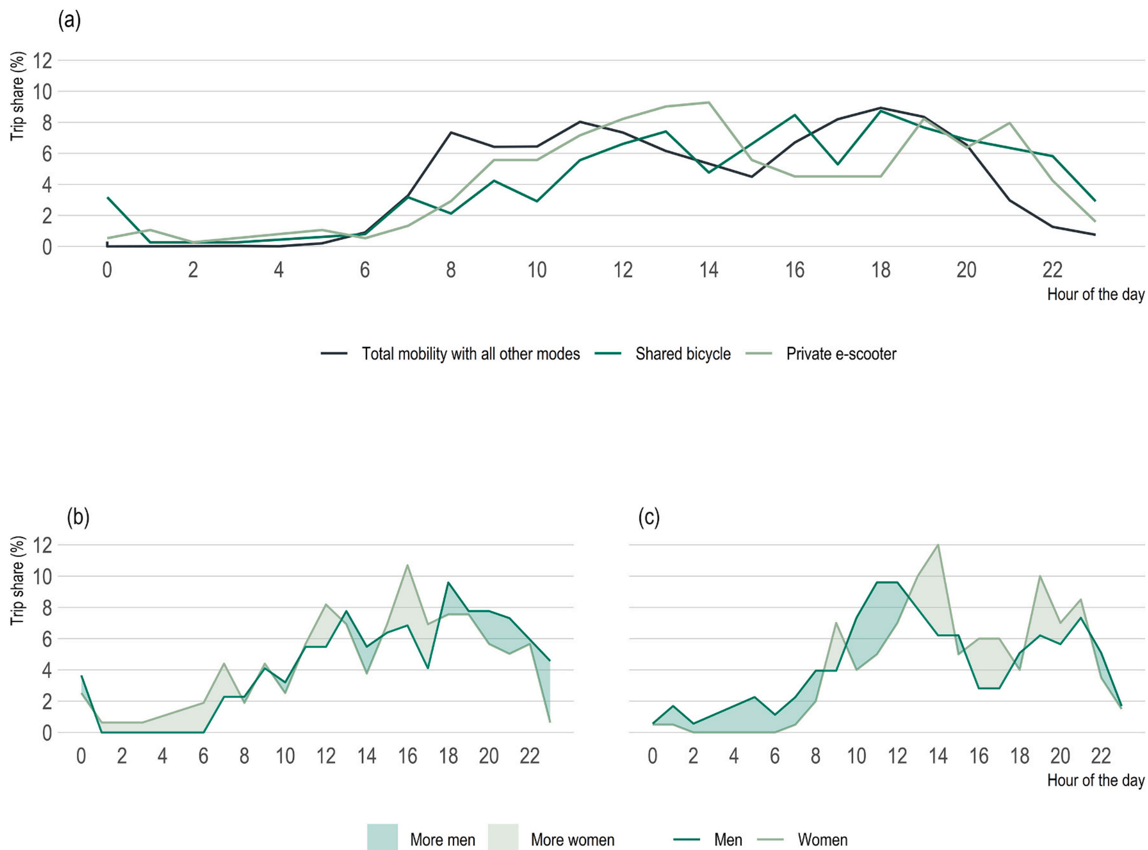

Fig. 3. (a) Hourly share of total and micromobility trips. (b) Hourly share of bike-share trips by gender. (c) Hourly share of private e-scooter trips by gender. Source: Own elaboration using travel data from IERMB (2020) for non-micromobility modes.

4.2. Speed patterns

The results of the model indicate that cycling facilities shape how cyclists and e-scooter riders navigate since vehicle speed significantly fluctuates depending on the urban environment its users are riding through (Table 2). The predicted speed for each cycling facility can be found in 'Appendix A Supplementary material'. Bicycle lanes are the cycling infrastructure where the highest speed is reached (with a predicted speed of 10.46 km/h), followed by pedestrianised streets (9.31 km/h), and bicycle sharrows (9.17 km/h). Together with the absence of cycling facilities (9.02 km/h), other urban elements that slow down the micromobility traffic flow are intersections (predicted difference of 0.72 km/h) and traffic lights (predicted difference of 0.86 km/h). Speed has not been found to differ significantly due to slope or time of day variables. Additionally, e-scooter users ride significantly slower than cyclists although it only translates into a 0.52 km/h predicted speed difference. Despite being significant, speed differences are not substantially meaningful when only considering single variables. Nevertheless, when transport mode is intersected with other variables (two- and three-way interactions), the model indicates that the speed at which e-scooters and bicycles are ridden is significantly influenced by the sociodemographic background of the participant.

To facilitate the interpretation of interaction terms in Table 2, we calculated the marginal effects of those that had tested for statistical significance in the model's analysis of deviance. Fig. 4 shows the predicted speed at which micromobility users drive, which has been adjusted for different transport modes, sociodemographic characteristics, cycling infrastructures and time of the day. Speed differences due to gender are more noticeable for e-scooter riders. Male e-scooter users ride faster than their female counterparts. Fig. 4 shows that these speed dissimilarities are greater in bicycle sharrows (with a predicted speed difference of 2.84 km/h). On the contrary, men and women cycle at similar speeds, with pedestrianised streets being the urban environment having a wider speed gap (speed difference of 1.88 km/h). The age group that travels the fastest are young (16–24 years of age) e-scooter riders (predicted speed of 11.30 km/h). According to our results, e-scooter users tend to slow down as they age. Although, we observe that men tend to postpone the beginning of this downward trend when compared to women. Among bicycle users, we see the opposite trend: young cyclists are the age group that travels the slowest (predicted speed of 8.44 km/h) and speed slightly increases as the age group changes. Moreover, having a child under 18 years seems to significantly decrease travel speed (predicted speed difference of 1.22 km/h). This reduction is notable among young women, whereas men experience it at later age stages. In general, micromobility users travel quicker at night, although these differences are more pronounced among women. However, when the results are disaggregated by transport mode, opposite gender patterns arise, which might be due to a small sample size of users travelling at night.

5. Discussion

Our results shed light on the influence of intersecting identities on the trip schedules, spatial preferences and travel speed of bike-share users and e-scooter riders navigating through Barcelona streets. In terms of timing, we found that bike-share and e-scooter trips overlap with commuting trips, a pattern also observed in the micromobility schemes of other cities (Li et al., 2020; Talavera-Garcia et al., 2021). Our findings, however, show that these modes are also highly used during the afternoon, especially by women, which might indicate a link between micromobility trips and non-work-related trip purposes. This is consistent with the findings in the study by Roig-Costa et al. (2021),

Table 2
Model 1. Micromobility users' speed according to sociodemographic attributes, street-network properties, and time variables.

		Coefficient	Std. Error	p-value*
	Intercept	12.51	0.74	
Infrastructure characteristics				
Cycling infrastructure	None	=ref	=ref	<0.001
	Bicycle lane	1.48	0.34	
	Bicycle sharrow	0.70	0.49	
	Pedestrianised street (<30 km/h)	0.69	0.46	
Intersection at 35 m	No	=ref	=ref	<0.001
	Yes	−0.65	0.15	
Traffic light or stop sign at 20 m	No	=ref	=ref	<0.001
	Yes	−0.87	0.15	
Net route slope		−0.01	0.01	0.202
Time variables				
Time of day	Morning (08:00–12:00)	=ref	=ref	0.096
	Afternoon (12:00–18:00)	−1.26	0.71	
	Evening (18:00–00:00)	−1.58	0.73	
	Night (00:00–06:00)	2.47	1.24	
Day of the week	Weekday	=ref	=ref	0.569
	Weekend	0.19	0.34	
Micromobility mode				
Mode	Bicycle	=ref	=ref	<0.001
	E-scooter	−0.22	1.03	
Sociodemographic variables				
Gender	Woman	=ref	=ref	0.995
	Man	−2.04	0.99	
Age	16–24	−0.73	0.82	
	25–34	=ref	=ref	0.784
	35–44	−0.02	0.91	
	>45	−1.60	1.24	
Having a child under 18 years	No	=ref	=ref	0.031
	Yes	−3.03	1.33	
Interaction terms				
Infrastructure characteristics				
Mode: Cycling infrastructure	E-scooter:Bicycle lane	−0.27	0.52	0.024
	E-scooter:Bicycle sharrow	−1.93	0.74	
	E-scooter: Pedestrianised street	−0.38	0.67	
Mode:Gender: Cycling infrastructure	Bicycle:Man:Bicycle lane	−0.75	0.47	0.030
	E-scooter:Man: Bicycle lane	1.14	0.57	
	Bicycle:Man: Bicycle sharrow	−0.49	0.65	
	E-scooter:Man: Bicycle sharrow	2.14	0.75	
	Bicycle:Man: Pedestrianised street	−1.17	0.63	
	E-scooter:Man: Pedestrianised street	0.36	0.69	
Time variables				
Gender:Time of day	Man:Afternoon	1.16	0.94	0.045
	Man:Evening	1.07	0.95	
	Man:Night	−5.23	1.72	
Mode:Gender:Time of day	E-scooter:Woman: Afternoon	1.06	0.97	0.014
	E-scooter:Man: Afternoon	−1.38	0.89	
	E-scooter:Woman: Evening	1.45	1.02	
	E-scooter:Man: Evening	0.00	0.98	
	E-scooter:Woman: Night	−6.41	3.22	
	E-scooter:Man:Night	2.61	1.63	
Micromobility mode				
Mode:Gender	E-scooter:Male	4.46	1.44	0.049
Mode:Age	E-scooter:16–24	4.27	1.43	0.001
	E-scooter:35–44	−1.51	1.34	
	E-scooter:>45	−0.25	1.31	
Mode:Gender:Age	E-scooter: Man:16–24	−5.07	2.14	0.030
	E-scooter: Man:35–44	−0.66	1.75	
	E-scooter:Man:>45	−4.07	1.85	
Sociodemographic variables				
Gender:Age	Man:16–24	1.24	1.21	0.854
	Man:35–44	1.32	1.16	
	Man:>45	3.53	1.51	
Gender:Age:Having a child under 18 years	Woman:25–34:Yes	0.67	1.80	0.011
	Man:25–34:Yes	2.58	2.15	
	Woman:16–24:Yes	−1.19	2.05	
	Man:16–24:Yes	2.85	1.68	
	Woman:35–44:Yes	3.76	1.74	
	Man:35–44:Yes	1.04	1.71	
	Woman:>45:Yes	4.76	1.71	
Random effects				
Route-specific		8.31	2.88	
User-specific		0.46	0.68	

* Analysis of Deviance (Type II Wald chi-square tests).

where it was noted that there is an association between micromobility use in Barcelona and personal purposes, and also with other similar findings in Gdansk (Bieliński and Ważna, 2020) and Vienna (Laa and Leth, 2020). During night hours, a significant gender gap is observed among cyclists, as men are much more likely to use the bike-sharing system than women starting from 18:00 onwards. Significantly, this gender gap is not found among e-scooter riders, which might have to do with differences in vehicle ownership and the docked nature of Barcelona's public bike-sharing systems. While privately owned e-scooters might be ridden door to door, bicycles must be picked up and parked in docking stations. This lapse of parking the bicycle and walking to the destination might slow cyclists' pace after a moment of increased visibility that is perceived to intensify harassment (Lubitow et al., 2019; Ravensbergen, 2022). This is also consistent with our finding that women cycle much faster at night. Accelerating to compensate for increased visibility is in line with other research, which noted that women develop specific strategies when cycling at night (Pellicer-Chenoll et al., 2021). Furthermore, it should be noted that bike-sharing trips duration might be constrained by their fee structure, with which individuals who surpass 30-min rides are charged (Bustamante et al., 2022).

On a spatial level, there are significant differences on how bicycles and e-scooters manoeuvre through different cycling infrastructure. Consistent with the literature, we found that bicycle lanes are the type of infrastructure leading to greater speeds for both shared bicycles and private e-scooters (Arellano and Fang, 2019; Flügel et al., 2019; Zuniga-Garcia et al., 2021). It is noteworthy that women subscribed to the bike-sharing system are the group that uses cycling infrastructure the least, particularly when it is shared with motorised vehicles. This result may

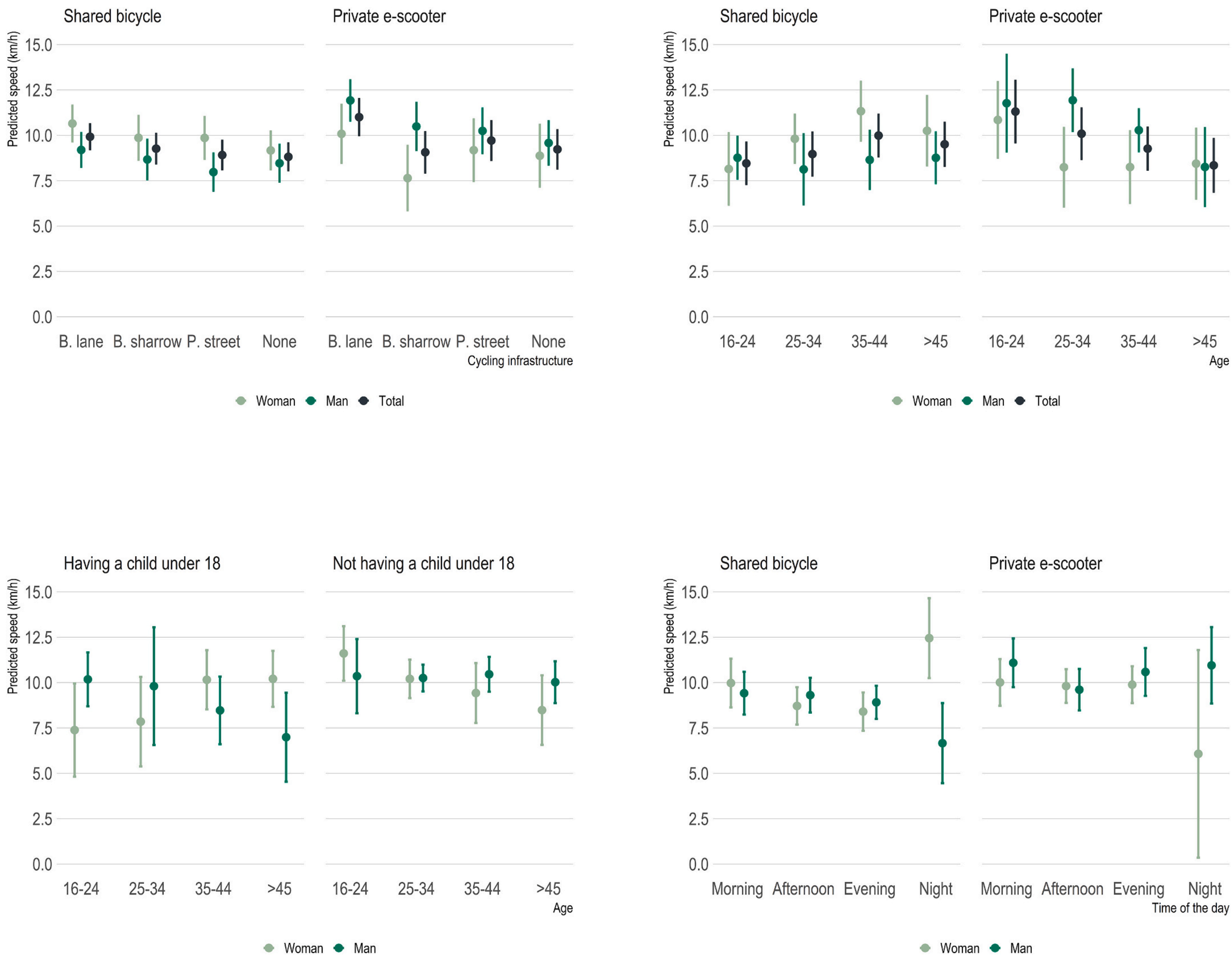

Fig. 4. Predicted travel speed (km/h) for interaction terms. Source: Own elaboration.

be explained by the fact that some women cyclists might feel discouraged to compete for their right to occupy that space, even in streets with fully dedicated cycling infrastructure (Heim LaFrombois, 2019; Ravensbergen, 2022; Sersli et al., 2022). This unwillingness to assertively negotiate traffic is more persistent in spatial contexts with strong norms of male appropriation of public space (Sayagh and Dusong, 2021) and Barcelona's traffic could be framed as one of such environments since the drivers' fleet is highly masculinised (Cubells et al., 2020). Avoiding cycling through traffic may also go hand in hand with an unwillingness to tolerate harassment from drivers (Balkmar, 2018; Graystone et al., 2022; Lubitow et al., 2019). Indeed, half of the women and non-binary cyclists who were surveyed in Barcelona reported to have experienced an aggression due to their gender identity or expression, and 30% of them stated that they had changed their route choice because of these encounters (Col·lectiu Punt 6, 2021). All in all, women cyclists in our sample seemed to use dedicated bike infrastructure at a lower rate than what would be expected.

Nonetheless, when women choose to circulate using the dedicated bike infrastructure, they tend to travel faster than the rest of the users, only being overtaken by men riding e-scooters. Our findings indicate that there is no gender gap in terms of speed among bike-share users, as no significant speed differences were found between men and women. These findings contradict previous studies on the subject (Flügel et al., 2019; Romanillos and Gutiérrez, 2020). They seem to be a result of women mirroring normative masculine fast-driving practices when using cycling facilities, as they might feel nudged to cycle rapidly to avoid 'feeling in the way' (Heim LaFrombois, 2019; Sersli et al., 2022). The tendency of women to either evade the cycling infrastructure or use it at higher speeds than expected would indicate that both strategies of desisting to compete for the lane and embodying fast cycling practices are coexisting at the same time in Barcelona's streets.

In contrast, women riding e-scooters appear to almost exclusively choose routes with dedicated cycling infrastructure. While they adopt similar speeds as cyclists, men riding e-scooters are the micromobility users who travel the fastest in each type of cycling facility, a finding that is also reported by Arellano and Fang (2019). Reckless men using micromobility modes have been identified to be problematic for other users riding at moderate speeds, as these users might feel discouraged to take the lane (Balkmar, 2018; Sersli et al., 2022). Risk-taking and fast-riding practices are examples of how careless masculinity, in this case, performed by micromobility users, can actively dissuade other potential users to share the same infrastructure, which would hinder the adoption potential of micromobility modes and hurt the prospects of a more sustainable mobility.

Intersecting identities in terms of gender, age and parenthood are observed to further influence how micromobility users travel. Age has not significantly explained the variance of prior speed models for bicycles, although the highest speeds were observed among middle-aged users (Flügel et al., 2019; Romanillos and Gutiérrez, 2020). The fact that middle-aged adults travel faster than younger adults could be associated with increased confidence, due to spending more time cycling (Sersli et al., 2022). According to our findings, whereas young bike-share cyclists are the age group that travels the slowest, young e-scooter riders are the age group that travels the fastest, especially men. This is in line with previous studies that identified young men riders as being more likely to perform risky behaviours (Gioldasis et al., 2021). Another factor that has been observed to shape micromobility users' performance is having children. Prior research revealed that cyclists acknowledged the fact that they travelled slower when cycling with children (Hatfield et al., 2019; Janke and Handy, 2019). Our results quantitatively show that parents of minor children ride at a slower pace, even when travelling alone. It should be noted that Barcelona's bicycle-sharing system does not support child bike seats or trailers, and that it is forbidden by law to carry passengers when using an e-scooter (Ajuntament de Barcelona, 2017). Therefore, our results suggest that having children permeates to travel behaviour, even when not travelling with minors, a finding that had been previously reported only for other transport modes (Maciejewska and Miralles-Guasch, 2019). Furthermore, being a parent seems to influence the travel behaviour of men and women at different age stages.

6. Conclusions

This article has explored the travel behaviour of bike-share cyclists and e-scooter riders using GPS-tracked trips. We have studied how micromobility users navigate multiple cycling facilities along the day to test whether (1) intersecting identities (in terms of gender, age and parenthood) influenced trip characteristics and spatiotemporal preferences and whether (2) axes of identity resulted in combined and overlapped travel patterns different than the simple accumulation of unidimensional identities. Indeed, our results have demonstrated that intertwined identities deeply influence riding behaviour among new micromobility users in ways that could not be explained by the sum of single sociodemographic characteristics. In particular, we have found that men and women have distinct travel behaviour, which is further defined by their age and whether they are parents. For instance, we have observed that child-care has opposite effects on riding speed for men and women depending on their age.

This study is not without limitations. We note that this analysis is specific to the urban context and mobility schemes of Barcelona. Further research is required to comprehend the applicability of the findings in other contexts and transport modes, such as private bicycles. In comparison to studies using smartphone GPS data, we gathered a smaller sample while overcoming some of their limitations concerning representativeness, at least in terms of gender parity. In addition, GPS data accuracy is not precise enough to capture the exact location of trips occurring on streets with different infrastructures, such as sidewalks, bicycle lanes, and roads. In these cases, it was assumed that cycling infrastructure was used. If cycling facilities were lacking, we could not determine whether users were circulating on the road or the pavement. Also, machine learning methods, in contrast to heuristic algorithms, promise to outperform trip detection in GPS trajectories in the future, which would increase the accuracy of trip characteristics and mode inference (Berjisian and Bigazzi, 2022). Finally, we acknowledge that this analysis could not account for the variation in gendered identities, and future research should be aimed at exploring the travel behaviour of other social groups of cyclists and riders, such as non-gender normative people or people with racialised experiences.

In conclusion, our study has provided a framework to acknowledge the intertwined nature of cyclists' and e-scooter riders' travel behaviour with axes of identity using objective spatial data. Our findings highlight the need to take an intersectional approach to individual characteristics when seeking to design policies aimed at regulating micromobility and create inclusive urban environments.

CRediT authorship contribution statement

Jerònia Cubells: Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft. **Carme Miralles-Guasch:** Resources, Supervision, Project administration. **Oriol Marquet:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Supervision, Project administration.

eclaration of Competing Interest

None.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtrangeo.2022.103502.

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