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Perceptions of safety and security among e-bike and e-scooter users in Iberian capital cities: Implications for urban mobility planning

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ABSTRACT

This study investigates perceived safety and harassment among e-bike and e-scooter users in Lisbon and Madrid, comparing privately owned and shared systems. Employing a mixed-methods approach, the research combines survey data with mental mapping, crash hotspot analysis, chi-square testing, Spearman correlation analysis, spatial risk modelling, and discourse interpretation to explore both objective and subjective dimensions of micromobility risk. A Spatial Risk Index (SRI) was developed to identify areas where crash density and user-perceived safety overlap. The findings revealed notable differences across user groups in terms of gender, age, length of residency, and vehicle ownership. Associations were also identified between crash incidence, urban topography, and the density of cycling infrastructure, while perceptions of safety were shaped by both physical conditions and the quality of public space. The results further underscore spatial mismatches between official crash records and areas perceived as dangerous by users, particularly in transitional or infrastructure-deficient areas. Distinct behavioural and perceptual patterns also emerged: users of shared systems tended to report lower engagement with safety equipment and higher levels of insecurity, while private users – although more frequent riders – faced greater exposure to harassment. Verbal harassment, especially among women and younger individuals, was commonly reported yet rarely disclosed to authorities, reflecting broader cultural and institutional barriers to reporting. The findings call for a more holistic and context-sensitive approach to micromobility planning – one that moves beyond individual behaviour or crash statistics alone. Urban policy should thus prioritise inclusive infrastructure design, consistent regulation, and the meaningful integration of user perspectives into safety and mobility strategies.

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1. Understanding urban e-micromobility risk: Safety, security, and spatial inequality

In recent years, the rapid expansion of micromobility – particularly e-bikes and e-scooters, both privately owned and shared – has reshaped urban mobility patterns across many European cities. Recent comparative analyses suggest that micromobility adoption is also shaped by underlying urban mobility cultures and structural network characteristics such as route circuity, with implications for mode choice and safety (Costa et al., 2025). Promoted as sustainable, low-carbon alternatives to car travel, these modes are frequently praised for improving accessibility, especially for short journeys and first- and last-mile connections (Santos et al., 2013; Lazarus et al., 2020). However, their integration into complex and unequal urban environments raises pressing concerns around safety, spatial justice, and social acceptability (Mayer, 2020; Teixeira et al., 2023). Alongside their growing popularity, micromobility vehicles have been increasingly involved in traffic crashes, many of which result in injuries of varying severity (Siman-Tov et al., 2017; Oksanen et al., 2020; Nielsen et al., 2021; Osti et al., 2023). This pattern is echoed in recent pan-European safety reports, which highlight the urgent need to improve micromobility regulation, rider behaviour, and infrastructure design to reduce severe injuries (Carson et al., 2024; Yannis et al., 2024). These risks are particularly visible in Southern European cities, where fragmented governance, intense tourism pressures, and pronounced socio-spatial polarisation present specific challenges to safe and equitable micromobility integration (Sequera & Nofre, 2020; Estevens et al., 2023; Popescu et al., 2023).

Lisbon and Madrid provide fertile ground for examining these dynamics. In both cities, the rise of micromobility has occurred in parallel with broader urban transformations, namely, touristification, gentrification, and housing market restructuring – which have led to resident displacement and the redefinition of public space (García-Hernández et al., 2017; Nofre et al., 2018; García-Hernández et al., 2019). These processes not only influence those who use micromobility, but also where and how it is used. Central areas, often saturated with tourism infrastructure and speculative real estate development, function as both attractors and contested zones for micromobility, a situation further complicated by uneven infrastructure provision (Lucato, 2020; Arias-Molinares et al., 2023).

While e-bikes and e-scooters offer significant potential to enhance urban accessibility and reduce car dependency (Santos et al., 2013; Ambrosino et al., 2016; de Haas et al., 2021; Gebhardt et al., 2022), multiple structural and socio-spatial barriers hinder their safe and inclusive adoption (Mayer, 2020; Sanders et al., 2020; Teixeira, Diogo, et al., 2023). In both Lisbon and Madrid, three interrelated conditions appear particularly influential in shaping micromobility experiences:

a) intense touristification and real estate-driven displacement of residents from central to peripheral areas (García-Hernández et al., 2019; Daly et al., 2020; Popescu et al., 2023);
b) complex urban morphologies that constrain infrastructure development in both central and outlying areas (Lucato, 2020; Costa et al., 2021; Freire de Almeida et al., 2021; Arias-Molinares et al., 2023); and
c) an inconsistent and fragmented institutional approach to micromobility governance (Ayuntamiento de Madrid, 2018; Charlotte & Sarti, 2020; Câmara Municipal de Lisboa, 2023).

Micromobility regulation in Portugal and Spain is guided by broader European directives (Comité Europeu de Normalização, 2022; Comité Europeu de Normalização, 2023), with e-scooters generally subject to the same legal frameworks as bicycles. In Lisbon, the regulatory environment is relatively lenient: there is no minimum age requirement, helmet use is recommended but not mandatory, and speed limits are set at 20 km/h for e-scooters and 25 km/h for e-bikes. Riding on pavements is prohibited, and parking is restricted to designated areas (Câmara Municipal de Lisboa, 2023; Ministério das Infraestruturas e da Habitação, 2024). In contrast, Madrid enforces stricter measures, including age thresholds (14 for e-scooters, 15 for e-bikes), mandatory helmet use for minors, and maximum permitted speeds of 25 km/h and 45 km/h respectively. Pavement parking is permitted since it does not obstruct pedestrian movement (Ayuntamiento de Madrid, 2018; Ministerio de la Presidencia, Justicia y Relaciones con las Cortes, 2024).

Within this institutional landscape, user safety must be understood both as a regulatory matter and as a lived, subjective experience. Although some studies have documented crash rates and helmet usage among e-scooter users (James et al., 2019; Reck et al., 2021), far fewer have explored how safety is perceived – and how such perceptions are shaped by gender, ownership models, prior experiences of harassment, and the built environment (Sanders et al., 2020; Cubells et al., 2023). Yet, gender remains systematically under-reported in micromobility research, creating a significant data gap that limits our understanding of differentiated safety experiences (Parnell, 2025).

Similarly, perceived insecurity has a significant influence on mobility choices, particularly for women, younger users, and other vulnerable populations (Sheller, 2018; Gössling, 2020). Yet, this subjective dimension remains largely overlooked, especially in socially stratified and heavily touristified urban contexts.

Previous research has highlighted a range of factors affecting micromobility safety and risk perception, including infrastructure availability (Costa et al., 2021), topography (Freire de Almeida et al., 2021), regulatory inconsistencies (Charlotte & Sarti, 2020), and symbolic boundaries within the city (Pereira et al., 2017). However, little attention has been given to how these elements interact with different ownership models (private versus shared) or vehicle types (e-bike versus e-scooter). This gap is particularly relevant given that shared micromobility tends to cluster in central districts, while private users may exhibit different travel patterns, exposure levels, and perceptions of risk.

More broadly, much of the literature continues to adopt a technocratic lens, privileging efficiency metrics, infrastructural provision, and crash reduction, while overlooking the socio-political and affective dimensions of mobility (Bertolini, 2005; Mayer, 2020). In addition, studies often remain methodologically narrow, seldom integrating diverse data sources or combining quantitative and participatory approaches. Comparative analyses at the city level are still uncommon (LaScala et al., 2000; Cubells et al., 2023), and few investigations incorporate tools such as discourse analysis, mental mapping, or spatial risk modelling. As a result, current literature offers limited understanding of how perceptions of risk are spatially produced, socially distributed, and institutionally mediated.

Against this background, this study addresses four interrelated research gaps. First, the subjective and emotional dimensions of micromobility – such as perceived insecurity and behavioural adaptation – are often overlooked (Haustein & Møller, 2016; Marincek, 2023). Second, broader structural determinants of risk perception, such as traffic composition and governance regimes, remain underexplored (Ederer et al., 2023; Sievert et al., 2023). Third, gendered vulnerabilities and experiences of harassment are inconsistently addressed, despite growing evidence of their impact on access and comfort (Voi Technology, 2022; Roig-Costa et al., 2024). Fourth, there is a need for more comparative, mixed-method approaches capable of capturing differences across urban morphologies and governance frameworks (Cubells et al., 2023; Tiznado-Aitken et al., 2024).

In response to rising concerns around micromobility safety[1] and security[2] (Heesch et al., 2011; BikeWalkKC, 2014; Kalakou et al., 2021; Marincek, 2023), this study addresses the identified gaps through a mixed-methods, comparative analysis of Lisbon and Madrid. Specifically, it aimed to:

- Analyse behavioural and sociodemographic differences between private and shared e-micromobility users in Lisbon and Madrid, with attention to gender, age, residency, and helmet use patterns.
- Assess how perceived safety and experiences of harassment vary by vehicle ownership, gender, and urban context, using mental mapping and discourse analysis.
- Identify spatial patterns of micromobility risk by combining crash data, perceived danger zones, and urban form variables (e.g., slope, infrastructure) through spatial risk modelling and correlation analysis.

Our triangulated approach captures the emotional, spatial, and structural dimensions of micromobility safety and security, situating them within broader processes of commodification, symbolic exclusion, and spatial injustice. A central contribution of this study is the development of a Spatial Risk Index (SRI), which combines crash data (Ayuntamiento de Madrid, 2024; Carson et al., 2024; Yannis et al., 2024) with user-generated mental maps to identify areas of overlapping subjective and objective risk. The SRI builds upon earlier stages of participatory mapping and spatial hotspot analysis, allowing for a more integrated and context-sensitive understanding of how micromobility risk is perceived and concentrated across contrasting urban morphologies.

The article is structured as follows. First, we present case studies, conceptual framework and methodological design. We then discuss the main findings, including spatial patterns and narratives of perceived risk. Finally, we reflect on the policy implications of our results for urban mobility justice and propose directions for future research. In doing so, this study not only advances theoretical understandings of perceived risk in micromobility but also informs policies toward more inclusive and just urban mobility systems.

2. Case study context: Lisbon and Madrid

This study focuses on Lisbon (Portugal) and Madrid (Spain), two Iberian capitals (Fig. 1) undergoing rapid urban transformation and distinct micromobility dynamics. According to recent mobility surveys, bicycle usage remains relatively low in both cities – accounting for just 1.3 % of trips in Lisbon and 0.8 % in Madrid – despite policy efforts to promote active modes of transport (Consorcio Regional de Transportes de Madrid, 2019; Instituto Nacional de Estatística de Portugal, 2022).

Lisbon is subdivided into 24 parishes, with varied topographical and socio-spatial characteristics. Average slope is 5°, though in some central and historic parishes – such as São Vicente or Santa Maria Maior – this exceeds 6.5°, posing challenges for cycling safety and infrastructure development. Avenidas Novas offers the densest cycling network, with 6.2 km/km^2 (EMEL, 2023), while several peripheral parishes lacked access to shared micromobility services at the time of data collection. These disparities coincide with demographic and economic inequalities (Instituto Nacional de Estatística de Portugal, 2022), including highly touristic parishes (e.g., Santa Maria Maior, with over 31,000 tourist beds) and areas of rising real estate pressure (Turismo de Portugal, 2023, Instituto Nacional de Estatística de Portugal, 2024).

Madrid, composed of 21 districts, presents a different urban morphology. Although flatter (2° average slope), it exhibits marked contrasts in micromobility access. While districts like Centro and Salamanca benefit from high-density cycling infrastructure with approximately 8.0 km/km^2 (Geoportal del Ayuntamiento de Madrid, 2023), several outer districts lacked shared bike systems at the time this study was conducted. Socio-spatial inequalities are further reflected in real estate values and population densities – Salamanca being the most expensive area with €6,650/m^2 (Portal Web del Ayuntamiento de Madrid, 2023b), while Centro, Chamberí and Tetuán surpass 25,000 residents/km^2 (Portal Web del Ayuntamiento de Madrid, 2023a).

These geographic and socio-economic contrasts – especially regarding infrastructure distribution, topography, and ongoing urban processes – form a critical backdrop for understanding patterns of micromobility adoption, perceived safety and security, and governance, as explored in the following sections.

3. Methodology: Mixed methods for spatial and perceptual analysis

This study adopts an interdisciplinary framework that draws on transport and mobility studies, environmental psychology, public

[1] Safety refers to the state of being protected from harm, danger, or risk of any injury occurring on the roads or within the transport systems.

[2] Security refers to the protection against the various forms of harassment while travelling, including physical or verbal aggression, intimidation, or discrimination.

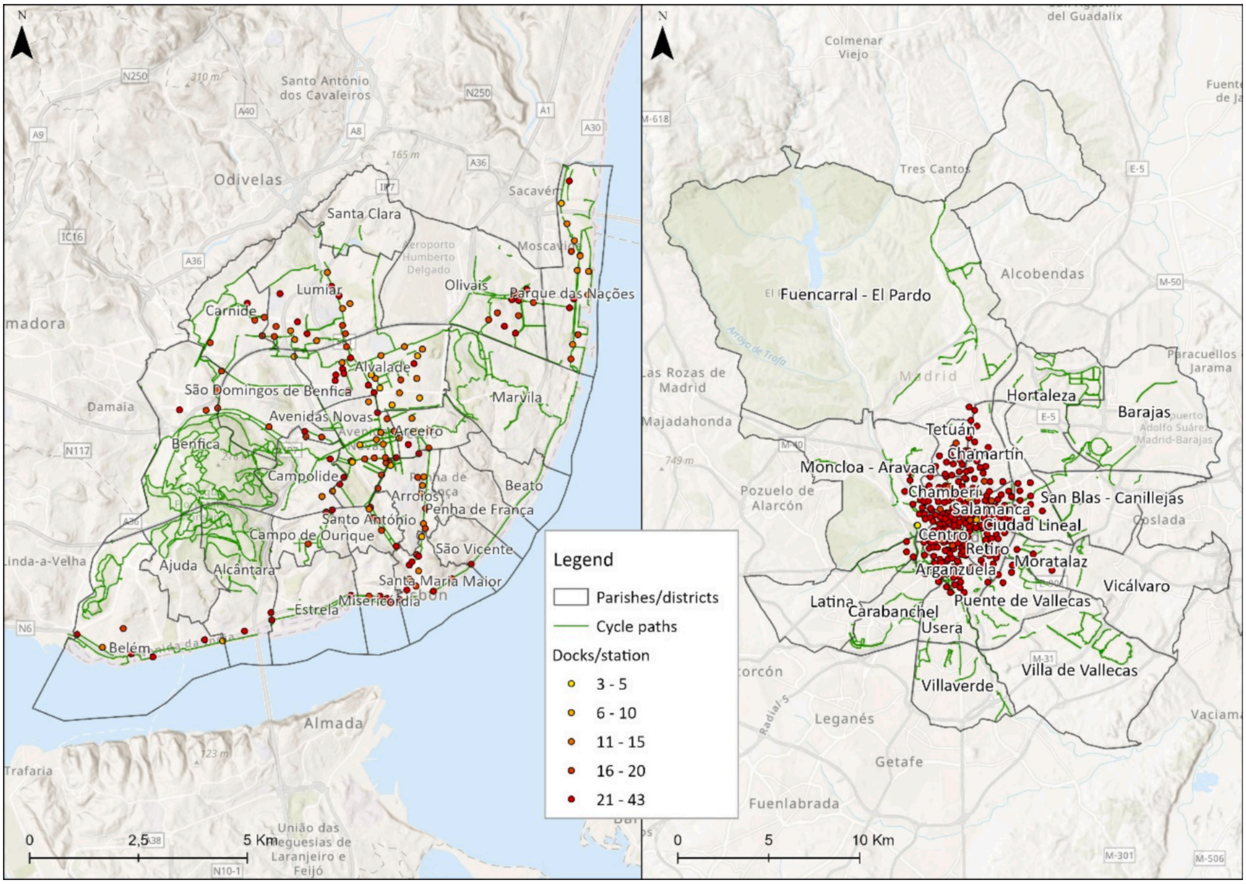

Fig. 1. Territorial administrative units of the case studies.

health, and urban studies to integrate infrastructure, behaviour, and both objective and subjective perceptions. The methodology follows a mixed-methods approach combining quantitative and qualitative techniques. This structure enables triangulation between spatial, statistical, and narrative dimensions, providing a multidimensional view of perceived micromobility risk in Lisbon and Madrid.

3.1. Survey administration

As the core empirical component of this study, we employed a quantitative research approach, utilising surveys to gather data through ESRI's ArcGIS Survey123 Connect software. The survey was developed based on a comprehensive literature review and assessed for both content and face validity. Feedback was obtained from mobility and transport research centres, followed by a pre-test with potential participants.

A non-probability convenience sampling method targeted regular and occasional users of both shared and privately owned e-bikes and e-scooters who were of legal age. The survey included single-choice, multiple-choice, Likert-scale, and open-ended questions, covering user experience, safety and security perceptions, and sociodemographic and mobility information (Fig. 2; Appendix A).

Sample sizes were estimated using McDole Rao (2004) formulas. Distribution occurred through social media, community associations, and NGOs. Participants were informed of the study's aims, consent was obtained, and anonymity guaranteed.

The survey was conducted in the two cities from March 2022 to May 2023, yielding 873 valid responses (475 from Lisbon – 320 of e-bike users and 155 of e-scooter users –, and 398 from Madrid – 233 of e-bike users and 165 of e-scooter users) (Table 1). In Lisbon, 52 % of e-bike users and 48 % of e-scooter users were renters, whereas in Madrid, renters comprised 67 % of both e-bike and e-scooter samples.

3.2. Quantitative data analysis

3.2.1. Descriptive and inferential statistics

Descriptive statistics were used to summarise user profiles and mobility behaviours across cities, modes, and ownership types. Although the study is based on a non-probabilistic convenience sample, we applied chi-square tests as inferential tools to explore internal patterns of variation – particularly across gender, city, vehicle type, and ownership model. These techniques, while not

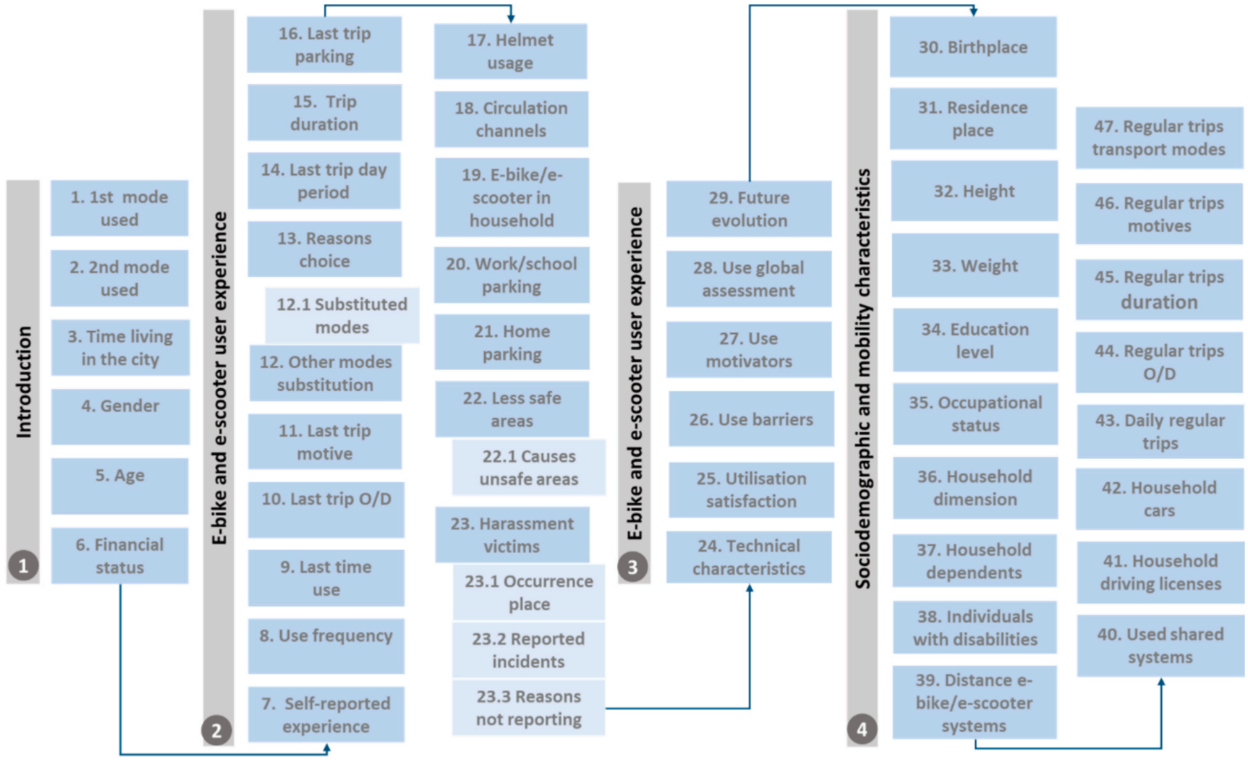

Fig. 2. Survey structure.

Table 1
Sample universe, responses, and margins of error.

City	User category	Sample universe	Data collection period	Answers	Error margin[a]
Lisbon	Non-users	359,333[b]	03/2022–11/2022 and 01/2023–04/2023	329	5.4 %
	E-bike users	5,486[c]		320	5.3 %
	E-scooter users	1,646[d]		155	7.5 %
Madrid	Non-users	2,385,900	10/2022–05/2023	325	5.4 %
	E-bike users	59,248[e]		233	6.4 %
	E-scooter users	14,315[f]		165	7.6 %

[a] A confidence level of 95 % was assumed (Z = 1.96).
[b] For non-users, the mobile population was used as a reference.
[c] Portugaĺs National Statistics Institute, 2018. Mobility Survey in the Lisbon Metropolitan Area, 2017. Available at: https://www.ine.pt/xportal/xmain?xpid = INE&xpgid = ine_publicacoes&PUBLICACOESpub_boui = 349495406&PUBLICACOESmodo = 2&xlang = pt.
[d] 30% of bicycle users – Cyclist and Scooter Rider Counts in Lisbon – November 2022 – Instituto Superior Técnico | CERIS – Filipe Moura, Rosa Félix, Madalena Santos, December 2022.
[e] Comunidad de Madrid, 2019. Mobility Survey of the Autonomous Community of Madrid, 2018. Available at: https://www.comunidad.madrid/en/servicios/transporte/encuesta-domiciliaria-movilidad.
[f] As there is no data on the number of e-scooter users, were assumed 50% of the trips made using other modes from the Mobility Survey of the Autonomous Community of Madrid, 2018.

enabling generalisation to the broader population, are commonly used in mobility perception research to reveal intra-sample differences and support exploratory interpretations (Teixeira et al., 2023; Sanders et al., 2020).

Sedgwick (2013) suggests that inferential techniques remain heuristically valid in convenience samples when interpreted with caution. This approach aligns with mobility justice frameworks, which emphasise the importance of revealing localised disparities in perceived safety, harassment, and access (Pereira et al., 2017; Sheller, 2018). Accordingly, our analysis aimed to identify group-specific experiences and spatial dynamics rather than aiming for statistical generalisability beyond the sample. Data analysis was carried out using R Studio and Excel software.

3.2.2. Correlation analysis

To explore associations between perceived safety and spatial-contextual variables, Spearman's rank-order correlation was employed. This non-parametric method is appropriate for ordinal data, non-normal distributions, and small spatial samples (Field, 2013; Thomas & DeRobertis, 2018). Separate analyses were conducted for Lisbon and Madrid, further disaggregated by micromobility mode and ownership type. Variables included crash counts, perceived safety scores, slope, altitude, and cycling infrastructure density, aggregated at the parish (Lisbon) or district (Madrid) level.

3.3. Crash data and spatial analysis

Crash statistics were collected from Ayuntamiento de Madrid (2024) and ANSR (2024), and complemented by European reports (Carson et al., 2024; Yannis et al., 2024). This data was used to map crash frequency and compare with user-reported perceptions of unsafe areas (see Section 4.2.3).

Hotspot mapping identified high-risk crash zones, while mental mapping captured spatial perceptions of insecurity (Anderson, 2009; Yavuz & Welch, 2010). These were integrated using a Spatial Risk Index (SRI) based on a 500 m x 500 m grid, normalised and combined through a multiplicative model. Classifications used natural breaks adjusted for consistency across cities and modes, with all the analyses performed in ArcGIS Pro.

3.4. Discourse analysis

Discourse analysis was employed to interpret how users articulate experiences of insecurity, harassment, and vulnerability. This method recognises that language both reflects and shapes social reality (Hajer, 1995; Fairclough, 2010; Gee, 2014). The analysis focused on 290 users who reported harassment, among whom 243 chose not to submit formal complaints. Of these, 184 provided narrative justifications, which were thematically analysed using the approach outlined by Braun & Clarke (2006). This process led to the identification of four inductively derived categories: perceived helplessness, fear of retaliation, institutional mistrust, and the normalisation of harassment. These offer insight into how insecurity is internalised and socially mediated, particularly among vulnerable groups such as women and younger users (Cubells et al., 2023; Wallgren et al., 2023).

4. Results: Subjective and objective risk in urban micromobility

This section presents the empirical findings derived from the survey, spatial mapping, statistical testing, and discourse analysis. Results are structured in three main parts: (4.1) user profiles, including socio-demographic characteristics and ownership patterns; (4.2) perceived safety and spatial risk factors, covering behavioural practices, spatial perceptions, crash patterns, and spatial convergence between subjective and objective risk; (4.3) perceived security and harassment, with a focus on underreporting and the social context of user vulnerability.

4.1. Sample characterisation

The final sample comprised 873 valid responses, including 475 from Lisbon and 398 from Madrid. Respondents included users of both private and shared e-bikes and e-scooters, with shared micromobility users accounting for 62.5 % of the total. E-scooter users slightly outnumbered e-bike users (54.3 % vs. 45.7 %).

The sample was predominantly male and composed largely of young adults aged 18–34. Most participants reported having lived in their respective cities for over five years, holding a university degree or higher, and being in employment. Some demographic variation emerged between user types and cities. Shared micromobility users included a higher proportion of women and students, while private users tended to have longer residence periods and more stable employment profiles. Lisbon users were generally younger and more likely to be recent residents than those in Madrid (see Table 2).

Chi-square tests revealed statistically significant differences across key sociodemographic variables, including age, gender, residency, education level, and employment status, both between cities and across ownership models (Appendix B). These findings highlight the heterogeneity of micromobility users and support the need for disaggregated analyses when assessing risk exposure and mobility experiences.

4.2. Perceived safety among e-bike and e-scooter users

4.2.1. Risky mobility patterns

Mobility behaviours and contextual practices reflect important dimensions of exposure to risk. Most respondents across both cities reported previous experience using e-bikes or e-scooters, particularly among private vehicle users. In contrast, shared system users – especially in Madrid – reported lower levels of regular usage. For instance, daily use was reported by 52.0 % of private e-bike users in Lisbon, compared to only 32.1 % of shared e-bike users. In Madrid, only 7.6 % of shared e-bike and 36.4 % of private e-scooter users used their vehicles daily. Moreover, sporadic use was far more common among shared system users: 21.6 % of shared e-scooter users in Lisbon and 40.9 % in Madrid fell into this category, while private vehicle users predominantly reported daily or weekly use Table 3.

Helmet use exhibited significant variation across user groups. Private users were more likely to report frequent use, while most shared system users indicated they never wore a helmet. Parking preferences further highlighted contrasting behaviours. Shared users mostly park in designated e-bike/scooter areas, whereas private users adopt more informal practices, such as securing vehicles to trees or buildings.

Table 2
Sample characteristics by city, vehicle type, and ownership model.

Gender	Lisbon										Madrid									
	E-bike users				E-scooter users				All (N = 475)		E-bike users				E-scooter users				All (N = 398)	
	Own (N = 152)		Shared (N = 168)		Own (N = 81)		Shared (N = 74)				Own (76)		Shared (N = 157)		Own (N = 55)		Shared (N = 110)			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Men	114	75.0 %	107	63.7 %	69	85.2 %	43	58.1 %	333	70.1 %	51	67.1 %	95	60.5 %	38	69.1 %	53	48.2 %	237	59.5 %
Women	36	23.7 %	58	34.5 %	12	14.8 %	30	40.5 %	136	28.6 %	22	28.9 %	56	35.7 %	16	29.1 %	52	47.3 %	146	36.7 %
Age																				
18–24 years	7	4.6 %	24	14.3 %	8	9.9 %	13	17.6 %	52	10.9 %	3	3.9 %	38	24.2 %	3	5.5 %	38	34.5 %	82	20.6 %
25–34 years	25	16.4 %	50	29.8 %	24	29.6 %	36	48.6 %	135	28.4 %	11	14.5 %	30	19.1 %	18	32.7 %	44	40.0 %	103	25.9 %
35–44 years	44	28.9 %	42	25.0 %	30	37.0 %	15	20.3 %	131	27.6 %	23	30.3 %	48	30.6 %	16	29.1 %	16	14.5 %	103	25.9 %
45–54 years	47	30.9 %	38	22.6 %	16	19.8 %	7	9.5 %	108	22.7 %	27	35.5 %	25	15.9 %	16	29.1 %	12	10.9 %	80	20.1 %
55–64 years	22	14.5 %	11	6.5 %	3	3.7 %	3	4.1 %	39	8.2 %	9	11.8 %	16	10.2 %	2	3.6 %	n/a	n/a	27	6.8 %
65 and more	6	3.9 %	3	1.8 %	n/a	n/a	n/a	n/a	9	1.9 %	3	3.9 %	n/a	n/a	n/a	n/a	n/a	n/a	3	0.8 %
Time living in the city																				
< 1 year	1	0.7 %	7	4.2 %	5	6.2 %	7	9.5 %	20	4.2 %	7	9.2 %	21	13.4 %	4	7.3 %	13	11.8 %	45	11.3 %
1–5 years	8	5.3 %	21	12.5 %	7	8.6 %	21	28.4 %	57	12.0 %	13	17.1 %	35	22.3 %	13	23.6 %	36	32.7 %	97	24.4 %
> 5 years	110	72.4 %	119	70.8 %	32	39.5 %	31	41.9 %	292	61.5 %	48	63.2 %	94	59.9 %	34	61.8 %	58	52.7 %	234	58.8 %
Commuters	31	20.4 %	20	11.9 %	30	37.0 %	10	13.5 %	91	19.2 %	6	7.9 %	2	1.3 %	4	7.3 %	1	0.9 %	13	3.3 %
Tourists	2	1.3 %	1	0.6 %	7	8.6 %	5	6.8 %	15	3.2 %	2	2.6 %	5	3.2 %	n/a	n/a	2	1.8 %	9	2.3 %
Education level																				
Primary school or lower	2	1.3 %	2	1.2 %	5	6.2 %	2	2.7 %	11	2.3 %	2	2.6 %	4	2.5 %	2	3.6 %	1	0.9 %	9	2.3 %
High school	18	11.8 %	15	8.9 %	28	34.6 %	13	17.6 %	74	15.6 %	13	17.1 %	33	21.0 %	14	25.5 %	43	39.1 %	103	25.9 %
University degree or superior	130	85.5 %	151	89.9 %	48	59.3 %	59	79.7 %	388	81.7 %	61	80.3 %	118	75.2 %	39	70.9 %	66	60.0 %	284	71.4 %
Professional situation																				
Student	9	5.9 %	28	16.7 %	5	6.2 %	14	18.9 %	56	11.8 %	1	1.3 %	43	27.4 %	3	5.5 %	44	40.0 %	91	22.9 %
Employed	134	88.2 %	132	78.6 %	69	85.2 %	60	81.1 %	395	83.2 %	70	92.1 %	110	70.1 %	50	90.9 %	65	59.1 %	295	74.1 %
Retired	4	2.6 %	5	3.0 %	n/a	n/a	n/a	n/a	9	1.9 %	3	3.9 %	2	1.3 %	n/a	n/a	n/a	n/a	5	1.3 %
Unemployed	4	2.6 %	2	1.2 %	6	7.4 %	n/a	n/a	12	2.5 %	1	1.3 %	1	0.6 %	2	3.6 %	1	0.9 %	5	1.3 %
Other	1	0.7 %	1	0.6 %	1	1.2 %	n/a	n/a	3	0.6 %	1	1.3 %	1	0.6 %	n/a	n/a	n/a	n/a	2	0.5 %

Table 3
Mobility practices and usage patterns of the sample by city, vehicle type, and ownership model.

	Lisbon										Madrid									
	E-bike users				E-scooter users				All (N = 475)		E-bike users				E-scooter users				All (N = 398)	
	Own (N = 152)		Shared (N = 168)		Own (N = 81)		Shared (N = 74)				Own (N = 76)		Shared (N = 157)		Own (N = 55)		Shared (N = 110)			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Self-reported experience																				
Experienced	95	62.5 %	87	51.8 %	36	44.4 %	27	36.5 %	245	51.6 %	60	78.9 %	111	70.7 %	41	74.5 %	64	58.2 %	276	69.3 %
With some experience	53	34.9 %	69	41.1 %	36	44.4 %	31	41.9 %	189	39.8 %	13	17.1 %	38	24.2 %	11	20.0 %	39	35.5 %	101	25.4 %
Beginner	3	2.0 %	11	6.5 %	8	9.9 %	16	21.6 %	38	8.0 %	3	3.9 %	8	5.1 %	3	5.5 %	6	5.5 %	20	5.0 %
Inexperienced	1	0.7 %	1	0.6 %	1	1.2 %	n/a	n/a	3	0.6 %	n/a	n/a	n/a	n/a	n/a	n/a	1	0.9 %	1	0.3 %
Use frequency																				
Daily	79	52.0 %	54	32.1 %	49	60.5 %	17	23.0 %	199	41.9 %	38	50.0 %	12	7.6 %	20	36.4 %	n/a	n/a	70	17.6 %
Weekly	58	38.2 %	79	47.0 %	20	24.7 %	19	25.7 %	176	37.1 %	28	36.8 %	51	32.5 %	27	49.1 %	30	27.3 %	136	34.2 %
Monthly	12	7.9 %	28	16.7 %	5	6.2 %	20	27.0 %	65	13.7 %	6	7.9 %	47	29.9 %	7	12.7 %	34	30.9 %	94	23.6 %
Sporadically	2	1.3 %	6	3.6 %	7	8.6 %	16	21.6 %	31	6.5 %	4	5.3 %	46	29.3 %	1	1.8 %	45	40.9 %	96	24.1 %
Only used once	1	0.7 %	1	0.6 %	n/a	n/a	2	2.7 %	4	0.8 %	n/a	n/a	1	0.6 %	n/a	n/a	1	0.9 %	2	0.5 %
Helmet use																				
Never	48	31.6 %	121	72.0 %	24	29.6 %	62	83.8 %	255	53.7 %	13	17.1 %	99	63.1 %	7	12.7 %	92	83.6 %	211	53.0 %
Sometimes	29	19.1 %	24	14.3 %	4	4.9 %	7	9.5 %	64	13.5 %	12	15.8 %	43	27.4 %	16	29.1 %	15	13.6 %	86	21.6 %
Frequently	75	49.3 %	23	13.7 %	53	65.4 %	5	6.8 %	156	32.8 %	51	67.1 %	15	9.6 %	32	58.2 %	3	2.7 %	101	25.4 %
Parking place preference																				
Garage	42	27.6 %	1	0.6 %	24	29.6 %	n/a	n/a	67	14.1 %	14	18.4 %	1	0.6 %	13	23.6 %	n/a	n/a	28	7.0 %
E-bike/e-scooter parking	39	25.7 %	144	85.7 %	6	7.4 %	40	54.1 %	229	48.2 %	14	18.4 %	114	72.6 %	3	5.5 %	23	20.9 %	154	38.7 %
Car parking	6	3.9 %	1	0.6 %	2	2.5 %	2	2.7 %	11	2.3 %	15	19.7 %	14	8.9 %	17	30.9 %	14	12.7 %	60	15.1 %
Against a tree/building	38	25.0 %	2	1.2 %	17	21.0 %	21	28.4 %	78	16.4 %	22	28.9 %	21	13.4 %	14	25.5 %	62	56.4 %	119	29.9 %
On the sidewalk	4	2.6 %	7	4.2 %	1	1.2 %	9	12.2 %	21	4.4 %	2	2.6 %	3	1.9 %	n/a	n/a	11	10.0 %	16	4.0 %
Other	23	15.1 %	13	7.7 %	31	38.3 %	2	2.7 %	69	14.5 %	9	11.8 %	4	2.5 %	8	14.5 %	n/a	n/a	21	5.3 %
Circulation channels																				
Cycle path segregated from road/sidewalk	123	80.9 %	124	73.8 %	48	59.3 %	45	60.8 %	340	71.6 %	51	67.1 %	87	55.4 %	26	47.3 %	48	43.6 %	212	53.3 %
Cycle path integrated into the road	13	0.7 %	17	10.7 %	12	11.1 %	11	13.5 %	53	11.2 %	8	7.9 %	19	18.5 %	9	16.4 %	19	26.4 %	55	13.8 %
Cycle path integrated into the sidewalk	1	8.6 %	18	10.1 %	9	14.8 %	10	14.9 %	38	8.0 %	6	10.5 %	29	12.1 %	9	16.4 %	29	17.3 %	73	18.3 %
No cycle path, but on the road	5	3.3 %	2	1.2 %	11	13.6 %	3	4.1 %	21	4.4 %	8	10.5 %	8	5.1 %	5	9.1 %	3	2.7 %	24	6.0 %
No cycle path, but on the sidewalk	n/a	n/a	n/a	n/a	n/a	n/a	1	1.4 %	1	0.2 %	1	1.3 %	1	0.6 %	2	3.6 %	2	1.8 %	6	1.5 %
Wherever they want, whenever they want	10	6.6 %	7	4.2 %	1	1.2 %	4	5.4 %	22	4.6 %	2	2.6 %	13	8.3 %	4	7.3 %	9	8.2 %	28	7.0 %

Circulation channel preferences also reflected safety concerns. Despite a strong preference for segregated infrastructure, many users – especially in Madrid – rely on shared paths or mixed-use spaces, often integrated into sidewalks or vehicular roads. (Babiano et al., 2017; Ekblad et al., 2016; Abad & van der Meer, 2018). These behaviours expose users to infrastructural inconsistencies and potential safety hazards, reinforcing earlier findings on perceived risk (Section 4.2.3).

Chi-square tests revealed that these behavioural differences were statistically significant across both cities and ownership types (Appendix B). For instance, parking behaviours, use frequency, and helmet use varied significantly between Lisbon and Madrid, as well as across shared and private user groups.

4.2.2. Crash frequency and user involvement

To complement perception-based insights, this subsection draws on official crash statistics for Lisbon and Madrid, sourced from national and municipal databases (Ayuntamiento de Madrid, 2024; ANSR, 2024), as well as pan-European safety reports (Carson et al., 2024; Yannis et al., 2024). This data enables comparison between perceived safety and actual crash patterns by micromobility mode.

In Lisbon, the annual number of reported bicycle-related crashes – including both conventional and e-bikes – fluctuated over the past decade, peaking at over 160 incidents in 2023. This increase corresponds with the post-pandemic expansion of bicycle use and the city's shared e-bike scheme (GIRA) development. E-scooter crashes were first recorded in 2019 and rose sharply to 93 incidents in 2022. However, a significant decrease was observed in 2023, following the implementation of a regulatory agreement with shared micromobility operators. This agreement introduced a 20 km/h speed limit, sidewalk riding bans, and designated parking restrictions (Câmara Municipal de Lisboa, 2023).

In Madrid, crash trends show a steady rise in bicycle-related incidents between 2011 and 2023, totalling 8,495 crashes with 9,490 injuries. Peak occurrences were recorded in 2019 (764 crashes). E-bike crash numbers remain lower but peaked in 2023 with 187 incidents. E-scooter crashes, on the other hand, have increased dramatically since 2019, culminating in 831 incidents in 2023, surpassing bicycle-related crashes for the first time (Fig. 3).

Fatalities remain relatively rare but non-negligible. In Lisbon, nine deaths were reported between 2011 and 2023, all involving bicycle users. In Madrid, 13 fatalities were recorded, comprising 12 bicycle users and one e-scooter user.

Crash involvement data from 2020 to 2023 reveal strong demographic patterns. In both cities, male users are significantly overrepresented among crash victims. In Lisbon, 79.7 % of bike and 72.5 % of e-scooter crash victims were men. Youth is another risk factor: among bike crash victims, 30.9 % were under 25 and 34.7 % aged 25–34. For e-scooters, 41.0 % were under 25 and 33.0 % aged 25–34.

Madrid displayed similar trends. Among bicycle and e-bike crash victims, 78.3 % were male and 20.1 % female, with 48.2 % aged under 35. E-scooter crash victims were also predominantly male (65.5 %), with 35.6 % under 25 and 30.6 % aged 25–34.

These patterns suggest a shared risk profile across cities: younger male users – particularly of e-scooters – are more frequently involved in crashes. This fact likely reflects a combination of behavioural, infrastructural, and exposure-related factors. When interpreted alongside survey results on use frequency and helmet habits, these findings indicate that vulnerability is heightened among frequent users of shared systems, where regulation and enforcement may be less consistent.

4.2.3. Spatial distributions of objective and subjective risk

Building on the spatial methodology outlined in Section 3.3, we compared crash data with user perceptions to identify urban areas of elevated micromobility risk. In Lisbon, bike crash hotspots were most pronounced in Arroios and Avenidas Novas, particularly along major arterial roads such as Almirante Reis and Avenida da República. E-scooter crashes were heavily concentrated in central locations, including Marquês de Pombal, Martim Moniz, and Cais do Sodré. In Madrid, both e-bike and e-scooter crashes clustered in central districts – Centro, Retiro, Salamanca, and Chamberí – with notable spill-over into Arganzuela and Barajas for shared e-scooters (Figs. 4 and 5).

Perceived safety patterns, based on user-generated mental maps, partially mirrored these objective risks. In Lisbon, private users

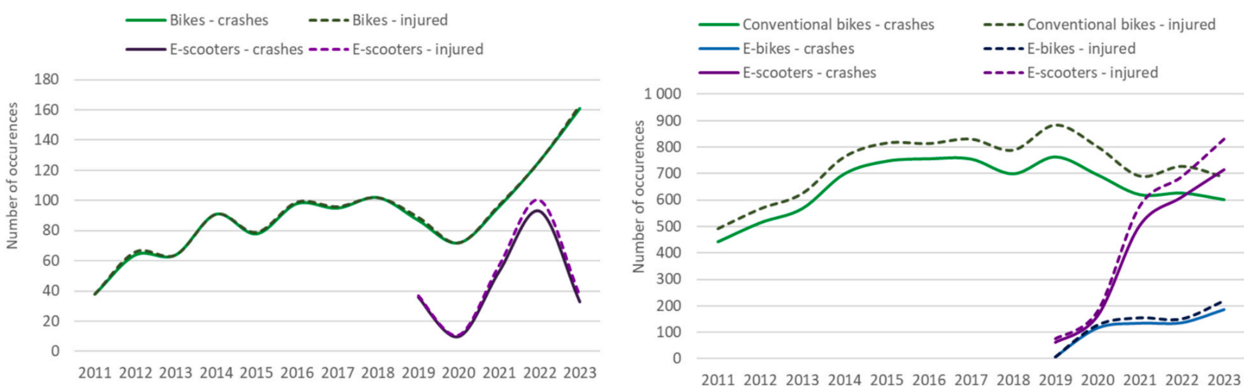

Fig. 3. Evolution of number of crashes by (e-)bike and e-scooter between 2011–2023 in Lisbon (right) and Madrid (left). Data source: Policía Municipal de Madrid, 2024 and ANSR, 2024

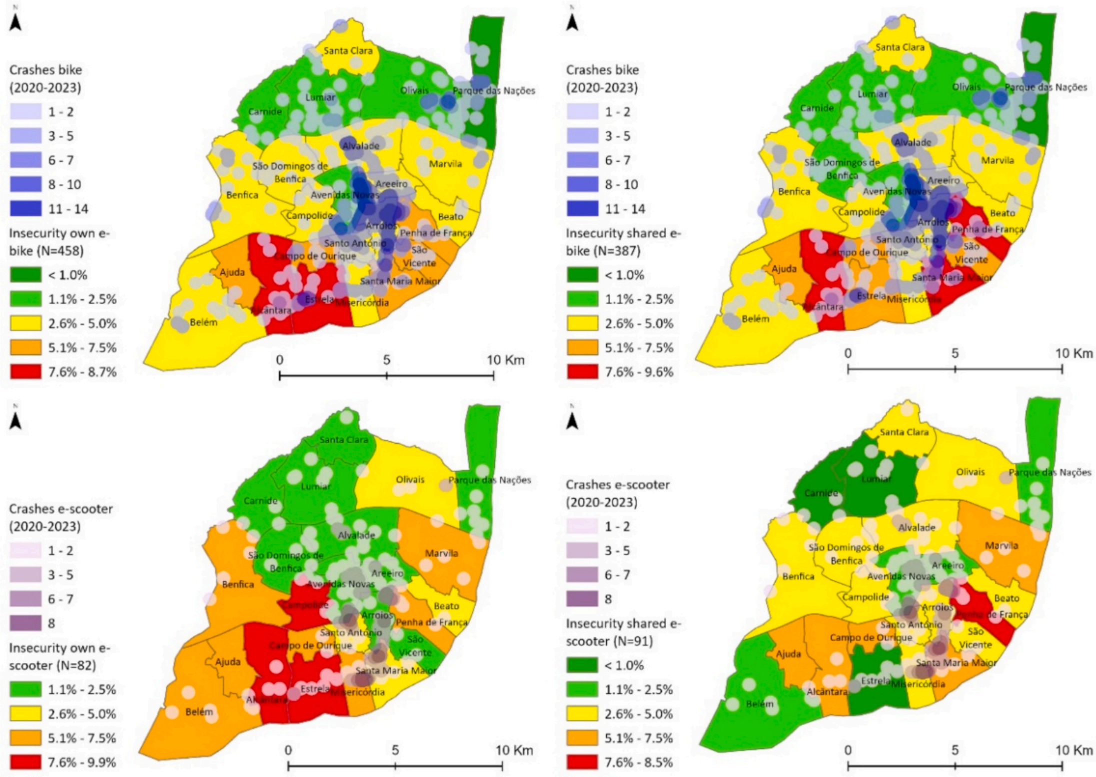

Fig. 4. Perceived safety by vehicle type and location in Lisbon. Data source for crash figures: ANSR, 2024.

frequently cited Alcântara and Estrela as particularly unsafe, while shared users highlighted Penha de França. In Madrid, Centro and Chamartín emerged consistently as high-risk zones across all user groups, with shared micromobility users also flagging Barajas. These divergences suggest that perceived safety is shaped not only by crash exposure but also by infrastructure gaps, traffic complexity, or personal experience.

Commonly reported reasons for identifying areas as unsafe included the absence of dedicated cycling infrastructure, high traffic volumes, and frequent conflicts with pedestrians. In Madrid, pedestrian congestion on micromobility paths – especially in tourist-heavy districts – was cited more frequently than in Lisbon, particularly by e-scooter users.

4.2.4. Spatial risk Index (SRI)

To capture spatial risk patterns that reflect both objective and subjective dimensions of micromobility safety, we developed a Spatial Risk Index (SRI). This composite indicator integrates crash frequency (2020–2023) with user-reported perceptions of safety. Both datasets were normalised and combined using a multiplicative model, based on the assumption that spatial risk intensifies where actual crashes and perceived danger coexist.

The resulting maps (Figs. 6 and 7) highlight both convergence and divergence between crash records and perceived safety. In Lisbon, high SRI values cluster along central mixed-traffic corridors and commercial areas, particularly affecting shared micromobility users. In Madrid, risk is more dispersed, with hotspots emerging in districts with high demand but limited infrastructure.

Importantly, zones where crash density overlaps with negative perceptions suggest systemic safety challenges. In Lisbon, such overlap is visible along Avenida Almirante Reis and Praça do Comércio – locations with high micromobility flows but fragmented infrastructure. In Madrid, convergence emerges in touristic and high-traffic zones such as Gran Vía and Retiro.

These findings underscore the value of integrating subjective experience into safety diagnostics. Several high-risk zones identified through the SRI had not been flagged by crash data alone, illustrating how perception-based tools can enhance proactive risk mitigation and inform more inclusive urban mobility planning.

4.2.5. Correlation analysis

To complement the spatial assessment, a non-parametric Spearman correlation analysis was conducted to examine associations between crash frequency, perceived safety, and urban form variables. The analysis was disaggregated by city (Lisbon and Madrid) and by micromobility mode (e-bike and e-scooter), considering both shared and private use.

Six core variables were tested: crash frequency – (e-)bikes and e-scooters, perceived safety, altitude, road slope, and cycling infrastructure density. Table 4 summarises statistically significant correlations, while the full matrices are presented in Appendix C.

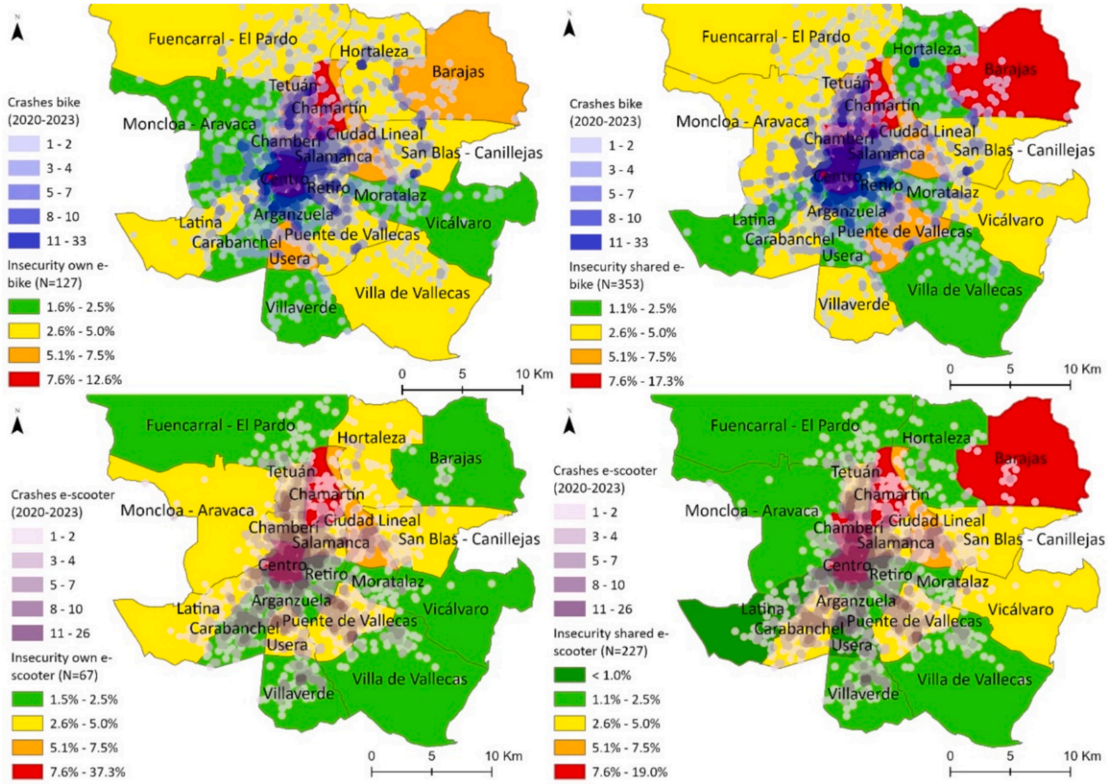

Fig. 5. Perceived safety by vehicle type and location in Madrid. Data Source for crash figures: Ayuntamiento de Madrid, 2024.

In Lisbon, crash frequency exhibited a significant negative correlation with slope ($\rho = -0.45$, $p < 0.05$), suggesting that flatter areas are more prone to incidents – likely due to higher usage. Perceived safety among both shared and private micromobility users correlated positively with slope, indicating that steeper zones are perceived as safer, possibly because they experience lower traffic or reduced micromobility flows.

In Madrid, crash frequency correlated positively with cycle infrastructure density for both e-bikes ($\rho = 0.60$, $p < 0.01$) and e-scooters ($\rho = 0.61$, $p < 0.01$), reflecting the spatial overlap between infrastructure provision and usage intensity. Additionally, perceived safety was positively correlated with altitude and infrastructure density – particularly among private users.

These results reinforce findings from the spatial analysis, highlighting how topography and infrastructure characteristics shape both actual and perceived safety. Importantly, they illustrate how micromobility risk is co-produced through structural conditions (e.g., slope, infrastructure distribution) and user perception, emphasising the need for integrated planning approaches.

4.3. Perceived security of e-bike and e-scooter users

Understanding security perceptions and experiences is key to promoting inclusive and equitable micromobility systems. This section explores users' self-reported experiences with harassment and the reasons why many such incidents remain unreported.

4.3.1. Harassment experiences and reporting patterns

Across the full sample (N = 873), 33.2 % of respondents reported having experienced at least one episode of harassment while using an e-bike or e-scooter. Rates were consistently higher among women (36.9 %) compared to men (30.5 %).

In both cities, private micromobility users reported higher rates of harassment than users of shared systems. In Lisbon, 53.9 % of private e-bike users experienced harassment, compared to 26.8 % of shared e-bike users. A similar trend was observed in Madrid, where 55.3 % of private e-bike users reported harassment, versus 26.1 % of those using shared systems (Table 5).. These results suggest that the shared nature of vehicles may offer a perceived – or possibly objective – layer of protection against harassment, potentially due to shorter trip durations, higher trip visibility, or differences in trip purpose.

These ownership-related differences were further compounded by gender. Among women in Lisbon, 77.8 % of private e-bike users reported harassment, compared to 25.9 % of shared e-bike users. In Madrid, although harassment rates were slightly lower among women in the same categories (59.1 % vs. 35.7 %), they remained significantly higher than those reported by men.

Despite this prevalence, reporting rates remained low – particularly in Lisbon. Fewer than 10 % of harassed users reported the

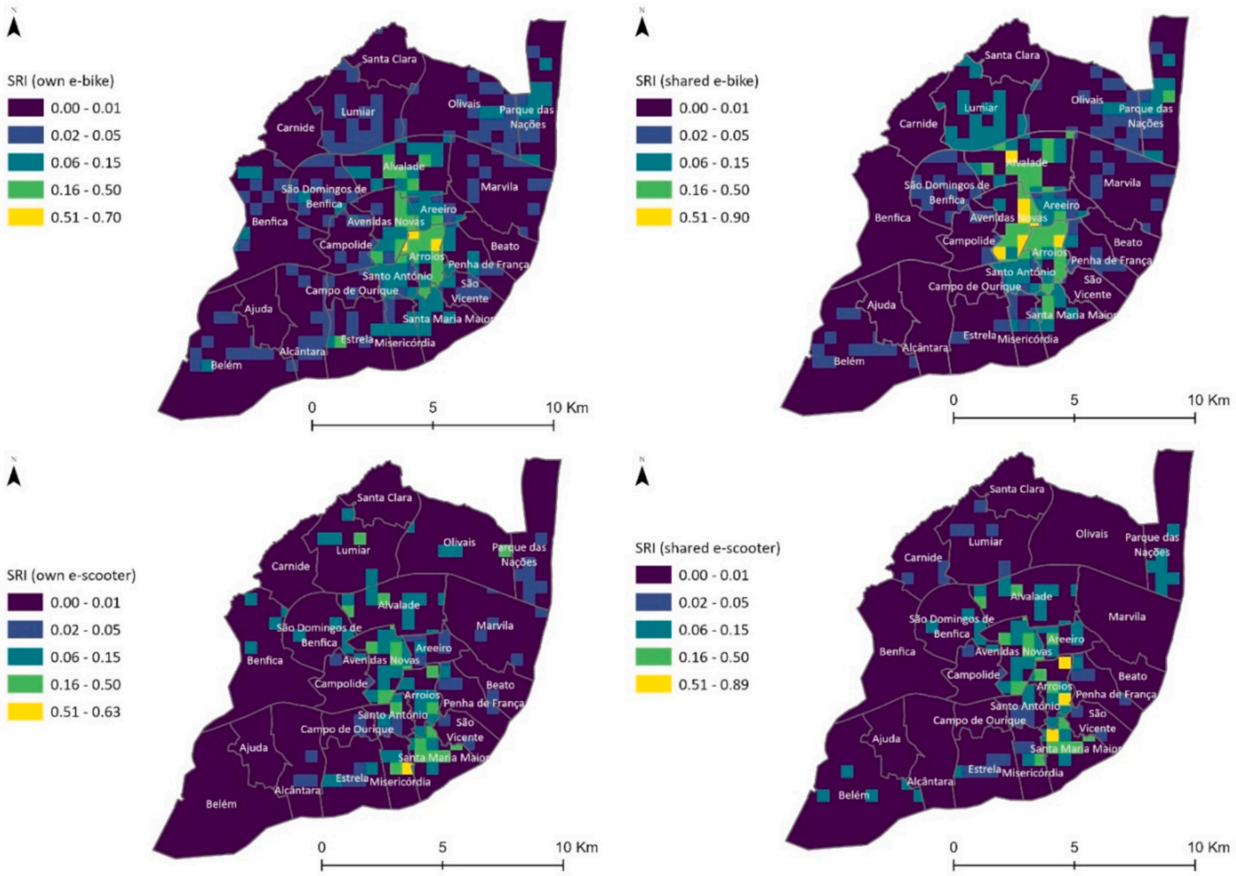

Fig. 6. Spatial Risk Index (SRI) combining crash density and perceived safety, by vehicle type (Lisbon).

incidents in most categories, except among shared e-scooter users (16.7 %). In Madrid, reporting was more frequent: at least 25 % of victims in each category stated they had filed a complaint or reported the episode. Women in Madrid showed the highest reporting engagement, with up to 46.1 % of female private e-bike users reporting harassment.

Nonetheless, the results point to clear patterns of gender-based underreporting – especially among men. For instance, in Lisbon, 46.5 % of male private e-bike users experienced harassment, but only 7.5 % reported it. In contrast, women showed higher awareness and responsiveness, though barriers still exist.

4.3.2. Barriers to reporting harassment

The content analysis of survey responses, performed manually based on topic frequency, permitted to identify and classify in four groups the perceptions of e-bike and e-scooter users regarding the factors influencing their decision to not report harassment episodes, namely:

(i) Incapacity to obtain relevant information about the aggressors

Many individuals frequently refrain from reporting instances of harassment due to the challenges associated with collecting relevant information regarding the perpetrator of the harassment. This can involve the acquisition of specific details of the individual's identity, thus potentially impeding the reporting procedure:

> *"I had no information about it. When you ride a scooter, it is impossible to take a photo with your mobile phone unless you stop the scooter"* (male, 25–34 years old, scooterist with some experience, Lisbon).
> *"The aggressor fled in his car, and I could not identify him"* (male, 35–44 years old, experienced cyclist, Lisbon).
> *"Lack of evidence because I did not have a camera"* (non-binary, 35–44 years old, experienced cyclist, Madrid).
> *"I was very nervous, and I would not have been able to identify him. I did not think about it either, it was a verbal assault, but it was very violent"* (woman, 45–54 years old, experienced cyclist, Madrid).
> *"Difficulty in identifying the license plate: I have a rear-view mirror on my bike, and, on several occasions, drivers were too close behind me and honked, forcing me to be attentive and not look at the details"* (male, 25–34 years old, experienced cyclist, Madrid).

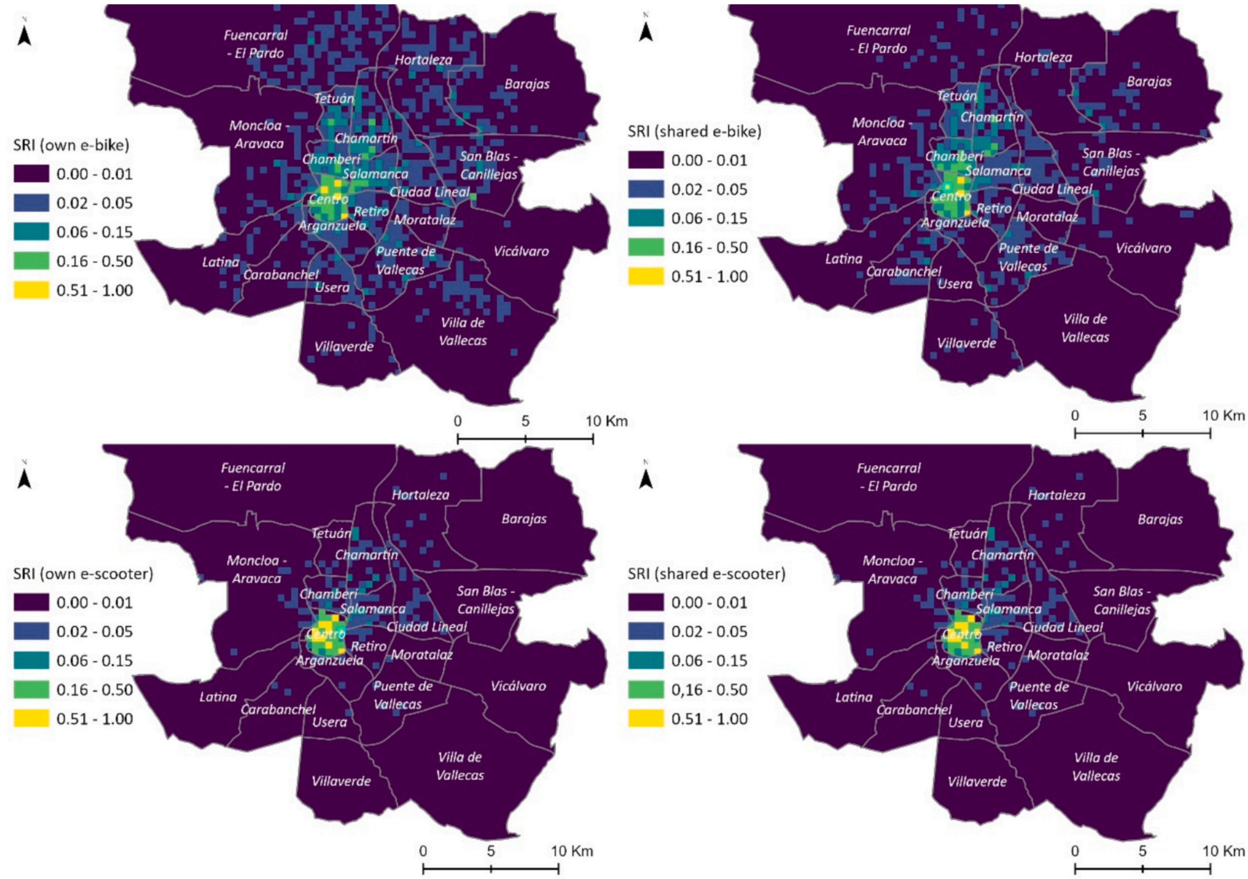

Fig. 7. Spatial Risk Index (SRI) combining crash density and perceived safety, by vehicle type (Madrid).

Table 4
Statistically significant Spearman correlations between perceived safety, crashes, and urban form variables in Lisbon and Madrid.

Variable 1	Variable 2	Spearman_rho	p_value	Significance	Dataset
Shared e-bike perceived safety	Slope	0.84	0.000	***	Lisbon – Bike
Own e-bike perceived safety	Slope	0.76	0.000	***	
Crashes with bikes	Slope	−0.45	0.029	*	
Shared e-scooter perceived safety	Slope	0.68	0.000	***	Lisbon –E-scooter
Own e-scooter perceived safety	Slope	0.46	0.023	*	
Crashes with bikes	Cycle network density	0.60	0.004	**	Madrid – Bike
Own e-bike perceived safety	Altitude	0.45	0.042	*	
Crashes with e-scooters	Cycle network density	0.61	0.003	**	Madrid – E-scooter
Own e-scooter perceived safety	Altitude	0.53	0.014	*	
Own e-scooter perceived safety	Cycle network density	0.46	0.036	*	

Significance: *** – p-value < 1 %; ** – p-value < 5 %; * – p-value < 10 %.

Generally, the perceptions reflect frustration and helplessness in the face of harassment. In many cases, individuals express their inability to gather evidence or identify the aggressors due to various reasons, such as the nature of the harassment, their safety, or the limitations of their vehicles. Additionally, other perceptions express fear, anxiety, and nervousness resulting from the harassment. The reference to sudden falls and aggressive behaviour from other road users indicates a sense of vulnerability and concern for personal safety.

(ii) Misconception about severity

Additionally, a common reason for not reporting the harassment occurrences is a misconception about the seriousness of the situation. Users might underestimate the severity of the harassment, leading them to believe that reporting is unnecessary:

Table 5
Harassment victims and reporting by gender, city, ownership model, and vehicle type.[g]

		Global				Women				Men			
		Harassment victims		Episodes reported		Harassment victims		Episodes reported		Harassment victims		Episodes reported	
		n	%	n	%	n	%	n	%	n	%	n	%
Lisbon	Own e-bikes (N = 152)	82	53.9 %	4	4.9 %	28	77.8 %	n/a	n/a	53	46.5 %	4	7.5 %
	Shared e-bikes (N = 168)	45	26.8 %	2	4.4 %	15	25.9 %	1	6.7 %	28	26.2 %	n/a	n/a
	Own e-scooters (N = 81)	27	33.3 %	2	7.4 %	4	33.3 %	1	25.0 %	23	33.3 %	1	4.3 %
	Shared e-scooters (N = 74)	12	16.2 %	2	16.7 %	3	10.0 %	1	33.3 %	8	18.6 %	n/a	n/a
	All (N = 475)	166	34.9 %	10	6.6 %	50	36.8 %	3	6.0 %	112	33.6 %	5	4.5 %
Madrid	Own e-bikes (N = 76)	42	55.3 %	15	35.7 %	13	59.1 %	6	46.1 %	27	52.9 %	8	29.6 %
	Shared e-bikes (N = 157)	41	26.1 %	15	36.6 %	20	35.7 %	9	45.0 %	18	18.9 %	6	33.3 %
	Own e-scooters (N = 55)	16	29.1 %	4	25.0 %	6	37.5 %	2	33.3 %	9	23.7 %	2	22.2 %
	Shared e-scooters (N = 110)	25	22.7 %	7	28.0 %	15	28.8 %	4	26.7 %	8	15.1 %	2	25.0 %
	All (N = 398)	124	31.2 %	41	33.1 %	54	37.0 %	21	38.9 %	62	26.2 %	18	29.0 %

[g] Minor discrepancies between totals and gender-disaggregated values may occur due to the exclusion of low-frequency gender categories (e.g., non-binary, prefer not to say) in subgroup analyses. These categories are included in global figures but omitted from detailed breakdowns to ensure clarity.

> *"It was anything serious, just kids"* (male, 35–44 years old, scooterist with some experience, Lisbon).
> *"I did not want to get upset. Ignoring is the best medicine"* (male, 25–34 years old, experienced scooterist, Lisbon).
> *"Because the harassment is almost permanent. If I had to report it every time, I would spend my life at the police station. In addition, I am not interested at all, because I can clearly see that there is very little interest in enforcing the mobility regulations"* (female, 35–44 years old, scooterist with some experience, Madrid).
> *"Because the world has too many idiotic, self-righteous men who yell s**t at other people all the time. I tell them that's inappropriate, and I keep biking. This happens regularly on an e-bike and on my normal bike, at least once a day"* (female, 35–44 years old, experienced cyclist, Madrid).

The perceptions of this group convey a sense of resignation, suggesting that individuals have grown accustomed to such episodes or believe confronting the aggressors is not worth the emotional energy. Other opinions indicate frustration with the lack of enforcement of regulations and a perception that reporting will not lead to meaningful change. Additionally, for some respondents, there is a sense of normalisation of harassment, suggesting that such events are a frequent occurrence in their biking/scooting experiences.

(iii) Lack of knowledge about reporting procedures

Users might choose not to report due to time constraints or because they prioritise other matters. Reporting can involve additional effort, and users might opt not to engage in the process due to other commitments. Nevertheless, many users might not know the proper steps to follow when reporting harassment episodes. The absence of clear information on how to report can be a barrier to acting:

> *"I did not realise I could report it. On the other hand, the situation was so tense that it did not even occur to me to take note of the taxi's license plate"* (female, 35–44 years old, experienced scooterist, Lisbon).
> *"I did not think about doing it at the time, it is the first time I think I could have done it. I did not do it, I think because I lacked knowledge"* (female, 25–34 years old, experienced cyclist, Lisbon).
> *"I did not know how to report it. I had not taken a photo"* (female, 35–44 years old, experienced cyclist, Lisbon).
> *"I have been yelled at to get out of the way, honked at, or passed too close when overtaking, but I do not think it is reportable. It is complicated. Fortunately, it happens less and less"* (female, 45–54 years old, experienced cyclist, Madrid).
> *"It is a task that requires a lot of time, although I know that if we do not report, we will not make any progress"* (male, 55–64 years old, cyclist with some experience, Madrid).

Additionally, some perceptions reflect a lack of awareness about the option to report harassment incidents. Individuals are not aware of the possibility of reporting, suggesting a potential need for more information and education on the matter. Other perceptions highlight the emotional impact of tense situations, where individuals were more focused on dealing with the immediate tension than collecting information for reporting. In contrast, some individuals believe that reporting is necessary for driving change and progress in addressing harassment.

(iv) Lack of confidence in authorities

Finally, users might lack trust in the authorities' ability to address the issue or feel a sense of helplessness or indifference from the responsible bodies. This can discourage them from reporting, as they believe their complaints will not lead to effective action:

> *"Weak response from the authorities to this type of occurrence"* (male, 45–54 years old, scooterist with some experience, Lisbon).

"Maybe because I think the authorities will not do anything about it" (male, 45–54 years old, inexperienced scooterist, Madrid).
"No practical real legal/criminal positive outcome, police do not care" (male, 45–54 years old, experienced cyclist, Lisbon).
"The process takes too much time and does not lead to anything" (male, 45–54 years old, experienced cyclist, Lisbon).
"Lack of time and an expedient electronic means to do it, total lack of response from the authorities when I invest time to do it through normal channels" (male, 35–44 years old, cyclist with some experience, Lisbon).
"Laws and authorities that protect aggressors" (male, 35–44 years old, experienced cyclist, Lisbon).
"I suspect that the police do not care about these matters. If I had to complain about all the idiots who own the traffic, I would not have a life" (male, 35–44 years old, experienced cyclist, Lisbon).
"Not worth the time for the incompetent and underpaid police corp" (male, 35–44 years old, experienced cyclist, Lisbon).
"It is cultural, I do not think telling the police the license plate number of someone who sped up to scare me on my bike changes behaviours. In fact, the police would not do anything. The way is different" (female, 25–34 years old, cyclist with some experience, Lisbon, Portugal).
"Too much bureaucratic hassle and time" (male, 45–54 years old, experienced cyclist, Madrid).
"I have not fixed the license plate. Moreover, I have absolutely no confidence in the seriousness of the police when it comes to reporting complaints of this kind. Anyone who rides a bike is always a suspect and a target to be knocked down" (male, 25–34 years old, experienced cyclist, Lisbon).

Respondents usually perceive reporting as time-consuming and ineffective, prompting scepticism about whether it would generate meaningful actions. It highlights broader systemic issues and cultural norms that some individuals believe may contribute to the lack of effective response from authorities.

5. Towards safer and more inclusive micromobility: Discussion of findings

5.1. Rethinking micromobility risk: Perceptions, space, and equity

This study confirms that micromobility risk is a multidimensional phenomenon that combines objective crash exposure with subjective feelings of insecurity. The Spatial Risk Index (SRI) developed in this research highlighted significant mismatches between crash locations and perceived unsafe areas, particularly in Lisbon. For example, central parishes like Alcântara and Estrela were frequently perceived as unsafe despite low crash counts. These findings align with prior research arguing that risk is co-produced through material, perceptual, and socio-spatial factors (Golledge, 1999; Kitchin & Freundschuh, 2000; Younes et al., 2023).

Dominant frameworks in micromobility safety often focus narrowly on crash prevention and helmet use promotion. However, such approaches overlook systemic failures related to urban design and social dynamics. Instead, an equity-oriented perspective is needed – one that integrates infrastructure, social vulnerability, and lived experience (Pereira et al., 2017; Sheller, 2018; Zhang et al., 2025). The disparities identified between cities, vehicle types, and ownership models reinforce the need for this integrated lens.

Although micromobility is increasingly framed as a public health concern (Huang, 2022; Osti et al., 2023), policy responses remain behaviour-centric. Our findings support a broader framing, where safety results not only from individual behaviour but from infrastructural continuity, regulatory clarity, and inclusion (Younes et al., 2023). Users' perceptions of danger stem from objective conditions – such as traffic density, infrastructure gaps, and exposure to harassment – and should therefore be integrated into formal safety diagnostics (Babiano et al., 2017; Abad & van der Meer, 2018; Ederer et al., 2023).

5.2. Infrastructure, exposure and perceived vulnerability

Differences in perceived safety and crash exposure between shared and privately-owned vehicles underscore the influence of spatial practices. Shared users tend to avoid high-risk zones, whereas private users more frequently use routes crossing central and high-traffic areas, often with limited dedicated infrastructure. This confirms previous findings that highlight the central role of continuous, segregated infrastructure in shaping both perceived and actual safety (Reynolds et al., 2009; Gioldasis et al., 2021; Lee & Sener, 2023; Sievert et al., 2023).

Topography also emerged as a key factor. In Lisbon, crash frequency negatively correlated with slope, while perceived safety positively correlated with slope for both shared and private modes. This suggests that users may avoid steep areas for practical or safety reasons, while those with greater confidence (e.g., experienced users, often private) continue using them (Haworth et al., 2021; Nikiforiadis et al., 2021). Meanwhile, the positive correlation between crash frequency and infrastructure density in Madrid reflects the concentration of users in central, more networked areas, thus highlighting the importance of complementing infrastructure with behaviour change initiatives and effective regulation enforcement (Yannis et al., 2024).

Sidewalk riding, often framed as unlawful behaviour, must be interpreted contextually. As observed by Mehranfar & Jones (2024), such practices frequently reflect infrastructure gaps rather than intentional rule-breaking. In this light, a Safe System approach is more appropriate – one that prioritises system-wide interventions and resilience over punitive measures (Ederer et al., 2023).

5.3. Safety practices, regulation, and behavioural differences

Our results revealed strong differences in safety practices between ownership types (Roig-Costa et al., 2024). Helmet use was significantly lower among renters than owners – with 72.0 % of shared e-bike users in Lisbon and 83.6 % of shared e-scooter users in

Madrid reporting never wearing a helmet. These patterns mirror global findings showing renters are less likely to use helmets, partly due to lack of access and spontaneity of use (Comer et al., 2020; Pourfalatoun et al., 2023).

Although helmets can reduce injury severity in specific crash scenarios (Schleinitz et al., 2018; Sievert et al., 2023), they do not address root causes of micromobility risk. Over-reliance on helmets can shift responsibility to the user and discourage adoption, especially among occasional or new riders (Høye, 2018). Instead, public health strategies should focus on systemic safety: improved lighting, street design, vehicle speed regulation, and behavioural education. Voluntary provision of helmets in shared systems may help (Comer et al., 2020; Pourfalatoun et al., 2023), but it should not substitute for structural reform.

These behavioural differences also intersect with age, gender, and experience – reaffirming the typology proposed by Dill & McNeil (2013), in which only a small segment of users are "Strong and Fearless", while the majority of users ride conditionally based on perceived safety. Our findings echo this pattern, showing that renters tend to be younger and less experienced (Della Mura et al., 2022; Mehranfar & Jones, 2024), which makes them more vulnerable to infrastructural gaps (Gogola, 2018; Dias et al., 2023), particularly in cities like Lisbon, where street design remains fragmented and regulatory frameworks are still maturing.

5.4. Harassment, underreporting and social deterrents

Experiences of verbal harassment and aggressive behaviour emerged as critical barriers to the broader uptake of micromobility, particularly among women and other vulnerable user groups. Discourse analysis revealed a widespread reluctance to report such incidents, echoing previous findings by BikeWalkKC (2014) and Heesch et al. (2011), who observed that most harassment in cycling contexts remains unreported due to perceptions of futility or fears of escalation. In our study, respondents frequently cited shouting, honking, and intimidation as common forms of aggression encountered during micromobility use. These patterns mirror the dynamics observed in public transport, where personal security concerns have long been recognised as impediments to equitable access (Loukaitou-Sideris & Fink, 2014; Ceccato & Loukaitou-Sideris, 2021).

While existing research on perceived security in e-micromobility has largely focused on conflicts between e-scooter riders and pedestrians (Pourfalatoun et al., 2023; Speak et al., 2023), the present study reveals a broader and more pervasive landscape of harassment, affecting both shared and privately owned modes. Notably, experiences differed across user types and gender. Private vehicle users, particularly women, reported a heightened sense of exposure and vulnerability, supporting earlier claims of gendered mobility experiences differences in the experiences of owners and renters (Fyhri et al., 2019; Haworth et al., 2021).

On the other hand, low reporting rates further underscore the influence of contextual, cultural, and institutional factors on security perceptions. The reluctance to report harassment was often linked to difficulties in identifying perpetrators, beliefs that the incident lacked sufficient gravity, limited awareness of reporting procedures, and a general mistrust in the responsiveness of authorities (Leoni et al., 2022). Such factors contribute to a culture of silence that disproportionately affects marginalised users and perpetuates feelings of insecurity.

These challenges require a multidimensional strategy rooted in both spatial planning and social justice. Interventions must go beyond infrastructure and encompass inclusive regulations, accessible reporting mechanisms, and sustained efforts to change cultural norms that normalise harassment. Prioritising the lived experiences of women and other vulnerable users is key to creating safer and more equitable micromobility systems. While technology may offer supplementary tools, it is through systemic change – anchored in empathy, accountability, and public engagement – that meaningful progress will be achieved.

6. Conclusions and implications for policy and planning

This study examined the complex interplay between infrastructure, perceived safety and security, crash distribution, user profiles, and micromobility practices in Lisbon and Madrid. By comparing private and shared e-bike and e-scooter use across both cities, it explored how spatial context, social identity, and regulatory environments shape risk exposure, behavioural patterns, and feelings of vulnerability.

Using a mixed-methods approach – including spatial analysis, statistical testing, and discourse interpretation – this study assessed both the objective and subjective dimensions of micromobility risk. Chi-square tests identified statistically significant differences across user profiles, ownership models, cities, and vehicle types, revealing internal variation despite the use of a non-representative sample. Discourse analysis focused specifically on reported experiences of harassment and the reasons for non-reporting, offering insight into the emotional and social dimensions of perceived insecurity.

The findings reaffirm that micromobility safety cannot be reduced to infrastructure or individual behaviour alone. Instead, it emerges from multi-layered interactions involving urban form, regulatory structures, user perceptions, and social dynamics. The Spatial Risk Index (SRI) exposed a clear divergence between official crash hotspots and user-perceived unsafe areas, particularly in peripheral and transitional urban zones. This underscores the inadequacy of relying solely on crash statistics to understand urban vulnerability.

Moreover, inferential analysis revealed significant differences in age, gender, residency, education, and usage frequency between users of shared and privately owned vehicles, and across the two cities. These internal variations were critical in interpreting risk exposure and behavioural responses. In this sense, private users were more likely to report frequent use and to wear helmets, whereas shared system users expressed higher insecurity and lower engagement with safety equipment.

Marked gender differences also emerged within the perceived security, particularly in reported experiences of harassment. Female users consistently expressed greater discomfort and vulnerability in public space. However, underreporting was common, influenced by perceptions of futility, fear of retaliation, and limited trust in institutional responses.

Drawing on these findings, five policy directions are proposed:

- Design for vulnerability: Urban planning should prioritise groups most exposed to risk, such as women, novice users, and young riders. Expanding segregated cycling infrastructure and improving lighting can reduce both perceived and actual threats.
- Reframe compliance issues: Behaviours such as sidewalk riding or helmet non-use often stem from systemic failures rather than user irresponsibility. These issues should be addressed by improving infrastructure and accessibility to safety equipment.
- Strengthen safety education and access: Public campaigns, shared equipment schemes, and incentives targeting renters and less experienced users can promote safer practices. Rental platforms should be encouraged to integrate helmet access and in-app safety guidance.
- Strengthen protections against harassment and insecurity: Clear mechanisms for reporting harassment – alongside public awareness and institutional support – are necessary to ensure safe micromobility environments, particularly for women.
- Incorporate perceptions into planning: Subjective safety perceptions offer valuable insights into spatial inequalities. Participatory tools such as mental mapping and discourse analysis should be embedded in planning and evaluation processes.

Taken together, these findings contribute to the reframing of micromobility safety and security as an issue of public health, gender equity, and spatial justice. By combining statistical, spatial, and discursive approaches, it provides a multidimensional evidence base to support more inclusive urban mobility strategies. Nonetheless, several limitations must be acknowledged. The use of convenience sampling and a lengthy questionnaire may have introduced self-selection bias and limited generalisability. Moreover, the crash data span a pandemic-affected period (2020–2023), which may not reflect typical travel behaviour. Inconsistencies in crash recording practices across cities may also affect comparability.

Further limitations include the absence of multivariate statistical modelling and the lack of disaggregated sociodemographic variables in the spatial analysis. Although chi-square and Spearman tests provided useful exploratory insights, future studies should employ more robust econometric techniques to explore causal relationships and interaction effects.

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CRediT authorship contribution statement

Adorean Emanuel-Cristian: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nofre Jordi:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **García-Juan Laura:** Writing – review & editing, Validation, Supervision, Methodology. **Moura Filipe:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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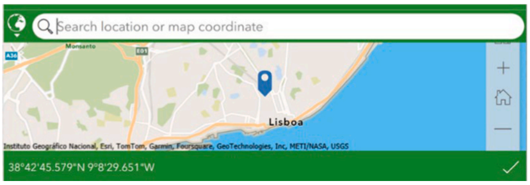
Appendix A. – Structure of the survey on e-bike and e-scooter users and non-users in the city of Lisbon[3]

Section 1 — **Introduction**	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above

(*continued on next page*)

[3] This version of the survey was applied in Lisbon. While the overall structure remained consistent across cities, the version used in Madrid was adapted to reflect local contexts. Adjustments included the use of Madrid's districts instead of Lisbon's parishes in questions related to residence and perceived unsafe areas, as well as updates to available transport modes and micromobility operators to reflect the local urban mobility system.

(*continued*)

Section 1 — Introduction	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
2. Besides the mode you use most often, do you also use any of the following?	o No o Yes, own e-bike o Yes, shared e-bike o Yes, own e-scooter o Yes, shared e-scooter
3. How long have you lived in the city of Lisbon?	o Less than 6 months o Between 6 months and 1 year o Between 1–3 years o Between 3–5 years o More than 5 years o I work/study in Lisbon, but live elsewhere o I am visiting Lisbon
4. What is your gender?	o Male o Female o Non-binary o Prefer not to say
5. How old are you?	o Between 18 and 24 years old o Between 25 and 34 years old o Between 35 and 44 years old o Between 45 and 54 years old o Between 55 and 64 years old o Over 65 years old o Prefer not to say
6. How would you describe your current financial situation?	o My income allows me to live without any difficulties o My income allows me to live moderately easily o I have financial difficulties o I have no income o Prefer not to say
Section 2 — E-bike/e-scooter user experience	
7. How would you rate your experience using an e-bike/e-scooter?	o Experienced o Some experience o Beginner o No experience
8. How often do you use, or have you used, an e-bike/e-scooter?	o Daily o A few times a week o A few times a month o Occasionally o I have only used it once
8.1 Why did you stop using e-bikes/e-scooters? (If "I have only used it once")	o I had an accident while using it o Lack of adequate infrastructure o Cost of use o Poor connection with other transport modes o Other:__________
9. When was the last time you used an e-bike/e-scooter?	o This week o Within the last 30 days o Within the last 6 months o Within the last year o More than a year ago
10.1 Please indicate on the map the origin of the last trip you made by e-bike/e-scooter in the city of Lisbon.	

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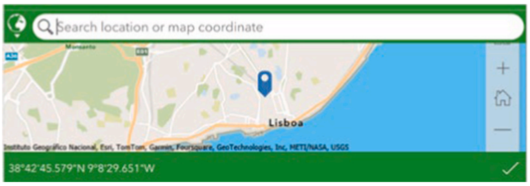
Section 1 — Introduction

1. Which of the following transport modes do you currently use or have used most frequently?
- o Own e-bike
- o Shared e-bike
- o Own e-scooter
- o Shared e-scooter
- o None of the above

10.2 Please indicate on the map the destination of the last trip you made by e-bike/e-scooter in the city of Lisbon.



11. What was the main purpose of your most recent trip by e-bike/e-scooter in Lisbon?
- o Leisure
- o Work
- o Education or training
- o Shopping
- o Medical appointments
- o Social services
- o Accompanying dependents (school, health centre, etc.)
- o Returning home
- o Other:__________

12. Did your last trip by e-bike/e-scooter replace another transport mode?
- o Yes
- o No

12.1 If yes, which mode of transport did it replace?
- o Walking
- o Motorbike
- o Shared motorbike
- o Bus
- o Metro
- o Train
- o Tram
- o Boat
- o Taxi or similar service
- o Car sharing
- o Car (as a passenger)
- o Private car
- o Other:______________

13. What were the main reasons for choosing an e-bike/e-scooter on your last trip?
- o Shorter travel time compared to other modes
- o Access to infrastructure (stations, cycle paths, etc.)
- o Ease of use
- o Lack of alternatives
- o Low cost
- o Good weather conditions
- o Health benefits
- o Environmental benefits
- o Other:__________

14. At what time of day did your last trip by e-bike/e-scooter take place?
- o Morning
- o Midday
- o Afternoon
- o Evening
- o Dinner time
- o Night
- o Early morning

15. Approximately how long did your last trip by e-bike/e-scooter take?
- o Less than 5 min
- o 6–10 min
- o 11–20 min
- o 21–30 min
- o 31–45 min
- o 46–60 min
- o More than 60 min

16. Where did you park the e-bike/e-scooter at the end of your trip?
- o On the pavement
- o Leaning against a building
- o Leaning against a tree or lamppost
- o On the road
- o In a car parking space
- o In a bicycle parking area
- o In a garage or storage room
- o Other:__________

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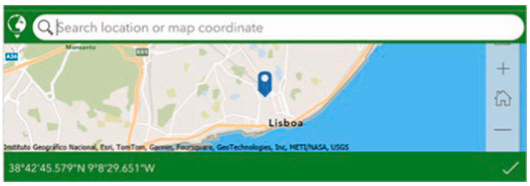
(*continued*)

Section 1 — **Introduction**	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
17. Do you usually wear a helmet when riding an e-bike/e-scooter?	o Yes, always o Yes, occasionally o No, I usually don't
18. Where do you generally prefer to ride an e-bike/e-scooter?	o Cycle path separated from road and pavement o Cycle path integrated into the road o Cycle path integrated into the pavement o On the road (no cycle path) o On the pavement (no cycle path) o Wherever I want, whenever I want
19. Is there any e-bike/e-scooter in your household that you can use?	o Yes o No
20. At your workplace/school, do you have a place to park bikes/e-scooters?	o Yes o Yes, subject to payment of a fee o No
21. Do you have a practical place to store a bike/e-scooter at your residence?	o Yes o No
22. In your opinion, which areas of the city are less safe in terms of infrastructure for riding an e-bike/e-scooter?	o I do not know/no opinion o Ajuda o Alcântara o Alvalade o Areeiro o Arroios o Avenidas Novas o Beato o Belém o Benfica o Campo de Ourique o Campolide o Carnide o Estrela o Lumiar o Marvila o Misericórdia o Olivais o Parque das Nações o Penha de França o Santa Clara o Santa Maria Maior o Santo António o São Domingos de Benfica o São Vicente
22.1 What factors contribute to making these areas feel unsafe?	o Heavy motor vehicle traffic o High pedestrian density o No cycle paths o Poor road or cycle path conditions o Steep road gradients o Inadequate traffic signs o Poor lighting o Other:__________
23. Have you ever experienced physical, verbal, or other forms of harassment while using an e-bike/e-scooter in Lisbon?	o Yes o No
23.1 Having answered you were harassed while you were using an e-bike/e-scooter in the city of Lisbon, please identify on the map the place where it happened, if you remember.	
23.2 Did you report the incident?	o Yes o No
23.3 If not, why didn't you report it?	_____________
Section 3 – **E-bike/e-scooter users' preferences and opinions**	

(*continued on next page*)

(*continued*)

Section 1 — **Introduction**	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
24. On a scale from 1 to 5, where 1 means Not at all important and 5 means Very important, how important are the following technical features of e-bikes/e-scooters to you?	▪ Manoeuvrability ▪ Braking system ▪ Gearshift system ▪ Battery ▪ Speed ▪ Climbing power ▪ Seat comfort[h]
25. On a scale from 1 to 5, where 1 means Completely dissatisfied and 5 means Completely satisfied, how satisfied are you with the following aspects of using e-bikes/e-scooters?	▪ Service area size ▪ Service area location[i] ▪ Number of available shared e-bikes/e-scooters[i] ▪ Existence of intermodal passes and/or special fares that include shared e-bikes/e-scooters[i] ▪ Parking options availability ▪ Ability to park bikes/e-scooters at stations/stops ▪ Existence of cycle paths in the city ▪ Cycle path conditions (cleanliness level, pavement quality, width, etc.) ▪ Connectivity to other existing transport modes in the city ▪ Facility to transport bikes/e-scooters on public transport vehicles ▪ Circulation through public spaces designated for pedestrian use ▪ Sharing space with motorised vehicles ▪ Speed and behaviour of motorised vehicle users ▪ Bus drivers' behaviour ▪ Taxi drivers' behaviour ▪ Possibility of travelling with bags or other bulky items ▪ Possibility of travelling with children or other dependents ▪ Health and physical benefits ▪ Safety and comfort during the trip ▪ Reduction in air and noise pollution ▪ Contribution to tackling global climate change
26. What is stopping you from using e-bikes/e-scooters more frequently in your daily trips?	▪ None ▪ Restricted size of the service area[i] ▪ Service area location[i] ▪ Availability of shared e-bikes/e-scooters[i] ▪ Lack of intermodal passes and/or special fares that include shared e-bikes/e-scooters[i] ▪ Lack of parking options ▪ Difficulty in parking bikes/e-scooters at stations/stops ▪ Lack of cycle paths in the city ▪ Poor conditions of cycle paths (cleanliness level, pavement quality, width, etc.) ▪ Lack of connection with other existing transport modes in the city ▪ Inability to transport bikes/e-scooters on public transport vehicles ▪ Need to share space with pedestrians ▪ Need to share space with motorised vehicles ▪ High speed and inappropriate behaviour of private car users ▪ Bus drivers' behaviour ▪ Taxi drivers' behaviour ▪ Difficulty in travelling with suitcases, shopping bags or other bulky items ▪ Difficulty in travelling with children or other dependents ▪ Reduced safety and comfort levels during the trip ▪ Unfavourable weather conditions ▪ Other:_____________
27. Which of the following improvements would make you more likely to use e-bikes/e-scooters?	o No improvements would make me use e-bikes/e-scooters more o Larger service area[i] o Better service area location[i] o More e-bikes/e-scooters available[i] o Existence of intermodal passes and/or special fares that include shared e-bikes/e-scooters[i] o More facilities to park bikes/e-scooters at stations/stops o More cycle paths in the city and near where I live and/or work o Better conditions of cycle paths (cleanliness, pavement quality, width, etc.) o Better connections to the existing transport modes in the city o Easier transport of bikes/e-scooters on public transport vehicles o More streets prioritised for cyclists o More road signs for bikes/e-scooters o Better battery autonomy

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Section 1 — Introduction	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
	o E-bikes/e-scooters with dedicated space for children o More reliable braking system o Improved suspension/shock absorber systems o Speed reduction and improved behaviour of private car users o Improved behaviour of bus drivers o Improved behaviour of taxi drivers o Easier transport of suitcases, shopping bags or other bulky items o Easier transport of children or other dependents o Increased safety and comfort during the trip o Availability of e-bike/e-scooter training lessons o Showers and lockers at work/school o E-bike/e-scooter insurance covering theft and/or damage o Financial incentives from employers/educational institutions (e.g. provision of e-bike/e-scooter as a service vehicle) o Other:_____________
28. Overall, on a scale from 1 to 10, where 1 means "Very Poor" and 10 means "Excellent", how would you rate the use of e-bikes/e-scooters in the city of Lisbon?	o 1 o 2 o 3 o 4 o 5 o 6 o 7 o 8 o 9 o 10
29. How do you foresee the evolution of e-bikes/e-scooters in the city of Lisbon?	_____________
Section 4 — Sociodemographic and mobility patterns	
30. Birthplace	Country:_____________County:_____________
31. In which parish do you currently live?	o Ajuda o Alcântara o Alvalade o Areeiro o Arroios o Avenidas Novas o Beato o Belém o Benfica o Campo de Ourique o Campolide o Carnide o Estrela o Lumiar o Marvila o Misericórdia o Olivais o Parque das Nações o Penha de França o Santa Clara o Santa Maria Maior o Santo António o São Domingos de Benfica o São Vicente o Other:_________
32. What is your height?	o Less than 1.50 *m* o Between 1.51 m and 1.60 *m* o Between 1.61 m and 1.70 *m* o Between 1.71 m and 1.80 *m* o Between 1.81 m and 1.90 *m* o More than 1.90 *m*
33. What is your weight?	o Less than 50 kg o Between 51 and 60 kg o Between 61 and 70 kg o Between 71 and 80 kg o Between 81 and 90 kg

(*continued on next page*)

(*continued*)

Section 1 — Introduction	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
	o Between 91 and 100 kg o More than 100 kg o Prefer not to answer
34. What is your level of education?	o I cannot read or write o 1st cycle of basic education o 2nd cycle of basic education o 3rd cycle of basic education o Secondary education o Post-secondary non-tertiary education o Undergraduate degree o Master's degree o Doctorate o Post-doctorate o Prefer not to say
35. What is your current professional situation?	o Student o Research fellow o Self-employed o Employee o Remote worker o Working student o Unemployed due to health reasons o Unemployed (other reasons) o Retired o Other:_____________
36. How many people live in your household, including yourself?	o 1 person o 2 persons o 3 persons o 4–6 persons o More than 6 persons o Prefer not to say
37. Are there any dependents in your household?	o No o Yes, pre-school child(ren) (under 5 years) o Yes, school-age child(ren) (5–10 years) o Yes, school-age child(ren) (11–16 years) o Yes, elderly relative(s) o Yes, individual(s) with physical or mental disabilities o Prefer not to say
38. Do you have any disabilities?	o No o Yes, mobility impairment o Yes, visual impairment o Yes, hearing impairment o Yes, cognitive impairment o Yes, other:_____________ o Prefer not to say
39. How far do you live from the nearest shared e-bike/e-scooter station?	o Less than 250 *m* o Between 251 and 500 *m* o Between 500 m and 1 km o Between 1 and 3 km o More than 3 km
40. Which of the following e-bike/e-scooter sharing services have you used?	o None o GIRA e-bikes o Bolt e-bikes o Bolt e-scooters o LINK e-scooters o Hive e-scooters o Lime e-scooters o Bird e-scooters o Whoosh e-scooters o Other:_____________
41. How many persons in your household hold a driving license?	o 1 person o 2 persons o 3 or more persons o None o Prefer not to say
42. How many cars are there in your household?	o 1 car

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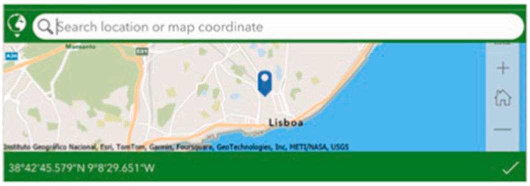
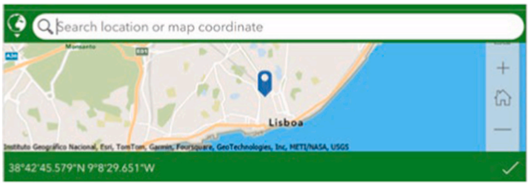
(*continued*)

Section 1 — **Introduction**	
1. Which of the following transport modes do you currently use or have used most frequently?	o Own e-bike o Shared e-bike o Own e-scooter o Shared e-scooter o None of the above
	o 2 cars o 3 or more cars o None o Prefer not to say
43. On average, how many trips do you usually make per day?	o None o 1 trip o 2 trips o 3 trips o 4 trips o 5 or more trips
44.1 Please indicate on the map the origin of your most frequent trip.	
44.2 Please indicate on the map the destination of your most frequent trip.	
45. What is the average duration of your regular daily trips?	o Less than 5 min o Between 6 and 10 min o Between 11 and 20 min o Between 21 and 30 min o Between 31 and 45 min o Between 46 and 60 min o More than 60 min
46. What is the main purpose of your most frequent trip?	o Leisure o Work o Education and training o Shopping o Medical appointments o Social services o Accompanying dependents (school, health centre, etc.) o Visiting the city o Other:_____________
47. Which modes of transport do you normally use on your regular trips	o On foot o Bicycle o E-bike o E-scooter o Motorbike o Bus o Metro o Train o Tram o Boat o Taxi or similar service o Car (as a passenger) o Private car o Other:_____________

[h] Applicable only to e-bike users.
[i] Applicable only to users of shared micromobility systems.

Appendix B. – Chi-square test results for sociodemographic and usage variables

Variable	Comparison	χ^2	df	p-value	Significance	City
Gender	Lisbon vs Madrid	4.87	3	0.1813		–
Age		18.78	5	0.0021	**	
Residence time		38.90	6	0.0000	***	
Education level		55.15	9	0.0000	***	
Professional situation		27.32	9	0.0012	***	
Use frequency		93.33	4	0.0000	***	
Helmet use		9.33	2	0.0094	**	
Parking preference		66.44	7	0.0000	***	
Circulation preference		21.52	5	0.0006	***	
Gender	Vehicle type (global)	7.09	3	0.0689	*	–
Age		45.17	5	0.0000	***	
Residence time		19.06	6	0.0041	**	
Education level		27.76	9	0.0010	***	
Professional situation		23.07	9	0.0060	**	
Use frequency		33.42	4	0.0000	***	
Helmet use		16.15	2	0.0003	***	
Parking preference		141.96	7	0.0000	***	
Circulation preference		12.48	5	0.0288	**	
Gender	Vehicle type	1.79	3	0.6168		Lisbon
Age		15.03	5	0.0102	**	
Residence time		25.36	6	0.0003	***	
Education level		11.78	7	0.1082		
Professional situation		11.94	8	0.1541		
Use frequency		30.29	4	0.0000	***	
Helmet use		4.01	2	0.1348		
Parking preference		58.08	7	0.0000	***	
Circulation preference		7.07	5	0.2152		
Gender	Vehicle type	5.75	3	0.1245		Madrid
Age		34.15	4	0.0000	***	
Residence time		6.17	6	0.4045		
Education level		16.80	8	0.0322	**	
Professional situation		16.81	9	0.0518	*	
Use frequency		11.63	4	0.0203	**	
Helmet use		13.93	2	0.0009	***	
Parking preference		86.64	7	0.0000	***	
Circulation preference		6.53	5	0.2581		

Significance: *** – p-value < 1 %; ** – p-value < 5 %; * – p-value < 10 %.

Appendix C. – Complete Spearman correlation results

Variable 1	Variable 2	Spearman_rho	p_value	Significance	Dataset
Crashes with bikes	Altitude	0.10	0.634		Lisbon – Bike
Crashes with bikes	Cycle network density	0.28	0.187		
Crashes with bikes	Own e-bike perceived safety	−0.40	0.054	*	
Crashes with bikes	Shared e-bike perceived safety	−0.42	0.042		
Crashes with bikes	Slope	−0.45	0.029	**	
Cycle network density	Altitude	0.36	0.082	*	
Cycle network density	Slope	−0.29	0.177		
Own e-bike perceived safety	Altitude	−0.24	0.259		
Own e-bike perceived safety	Cycle network density	−0.15	0.472		
Own e-bike perceived safety	Shared e-bike perceived safety	0.93	0.000	***	
Own e-bike perceived safety	Slope	0.77	0.000	***	
Shared e-bike perceived safety	Altitude	−0.39	0.060	*	
Shared e-bike perceived safety	Cycle network density	−0.28	0.190		
Shared e-bike perceived safety	Slope	0.84	0.000	***	
Slope	Altitude	−0.22	0.314		
Crashes with e-scooters	Altitude	−0.19	0.363		Lisbon – E-scooter
Crashes with e-scooters	Cycle network density	0.15	0.490		
Crashes with e-scooters	Own e-scooter perceived safety	−0.33	0.111		
Crashes with e-scooters	Shared e-scooter perceived safety	−0.39	0.060	*	
Crashes with e-scooters	Slope	−0.36	0.081	*	
Cycle network density	Altitude	0.36	0.082	*	
Cycle network density	Slope	−0.29	0.177		
Own e-scooter perceived safety	Altitude	−0.22	0.309		
Own e-scooter perceived safety	Cycle network density	−0.09	0.683		

(continued on next page)

(*continued*)

Variable 1	Variable 2	Spearman_rho	p_value	Significance	Dataset
Own e-scooter perceived safety	Shared e-scooter perceived safety	0.34	0.106		
Own e-scooter perceived safety	Slope	0.46	0.023	**	
Shared e-bike perceived safety	Cycle network density	−0.10	0.635		
Shared e-scooter perceived safety	Altitude	0.04	0.858		
Shared e-scooter perceived safety	Slope	0.68	0.000	***	
Slope	Altitude	−0.22	0.314		
Crashes with bikes	Altitude	0.22	0.344		Madrid – Bike
Crashes with bikes	Cycle network density	0.60	0.004	**	
Crashes with bikes	Own e-bike perceived safety	0.18	0.428		
Crashes with bikes	Shared e-bike perceived safety	0.07	0.761		
Crashes with bikes	Slope	0.40	0.074	*	
Cycle network density	Altitude	0.28	0.211		
Cycle network density	Slope	0.03	0.907		
Own e-bike perceived safety	Altitude	0.45	0.042	**	
Own e-bike perceived safety	Cycle network density	0.25	0.266		
Own e-bike perceived safety	Shared e-bike perceived safety	0.56	0.009	**	
Own e-bike perceived safety	Slope	−0.11	0.624		
Shared e-bike perceived safety	Altitude	0.38	0.088	*	
Shared e-bike perceived safety	Cycle network density	0.30	0.189		
Shared e-bike perceived safety	Slope	−0.02	0.937		
Slope	Altitude	0.21	0.354		
Crashes with e-scooters	Altitude	0.08	0.720		Madrid – E-scooter
Crashes with e-scooters	Cycle network density	0.61	0.003	**	
Crashes with e-scooters	Own e-scooter perceived safety	0.36	0.114		
Crashes with e-scooters	Shared e-scooter perceived safety	0.30	0.192		
Crashes with e-scooters	Slope	−0.11	0.624		
Cycle network density	Altitude	0.28	0.211		
Cycle network density	Slope	0.03	0.907		
Own e-scooter perceived safety	Altitude	0.53	0.014	**	
Own e-scooter perceived safety	Cycle network density	0.46	0.036	**	
Own e-scooter perceived safety	Shared e-scooter perceived safety	0.39	0.083	*	
Own e-scooter perceived safety	Slope	0.10	0.656		
Shared e-scooter perceived safety	Altitude	0.30	0.180		
Shared e-scooter perceived safety	Cycle network density	0.45	0.039	**	
Shared e-scooter perceived safety	Slope	−0.00	0.989		
Slope	Altitude	0.21	0.354		

Significance: *** – p-value < 1 %; ** – p-value < 5 %; * – p-value < 10 %.

Data availability

Data will be made available on request.

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