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How do regulations and safety perceptions affect the willingness to use e-scooters?

Ely Izquierdo-Herazo [a,b], Mauricio Orozco-Fontalvo [c,d], Margareth Gutiérrez [e,*], Raúl Ramos [b,f], Víctor Cantillo [a]

[a] Department of Civil Engineering, Universidad del Norte, Barranquilla, Colombia
[b] Proyectos Técnicos Ltda., Barranquilla, Colombia
[c] CERIS, Instituto Superior Tecnico, Universidade de Lisboa, Av. Rovisco Pais, 1, 1049-001, Lisboa, Portugal
[d] Program of Civil Engineering, Universidad Militar Nueva Granada, Bogotá, Colombia
[e] Center for Research and Innovation, Viña Concha y Toro, Santiago, Chile
[f] Department of Transport Engineering and Logistics, Pontificia Universidad Católica de Chile, Santiago, Chile

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ABSTRACT

The growing popularity of electric scooters has been accompanied by discussions about the regulations needed to reduce the externalities associated with their use. This study analyzes the influence of regulations and perceptions of *road unsafety* on the willingness to use e-scooters. For this purpose, we developed a hybrid discrete choice model (HCM). The model links sociodemographic characteristics and regulations on operational attributes using data from a stated preference survey conducted in Bogotá, Colombia. The influence of regulations is mixed. Results suggest that road safety measures, such as mandatory helmet use and restricting e-scooters circulation to bike lanes and streets (banning them from pedestrian walkways), increase the willingness to use e-scooters. In contrast, parking restrictions, high fares, and the imposition of fines for violations negatively impact the intention to use e-scooters. Furthermore, perceptions of road unsafety negatively influenced the willingness to use e-scooters. A significant interaction was observed between perceptions of *road unsafety* and regulations, suggesting a greater acceptance of these policies among individuals who perceived e-scooters as unsafe.

1. Introduction

Electric scooters, or e-scooters, are a relatively new mode of transportation that has gained popularity in urban mobility (Northway et al., 2022; Orozco-Fontalvo et al., 2023). They can be used as personal vehicles or as part of shared-use systems. Regarding the latter, dockless shared e-scooters stand out since they allow users to leave the devices anywhere instead of requiring scooters to be returned to fixed docking stations (Fang et al., 2018; Villa-Zapata et al., 2024). E-scooters should be preferred over other non-active transport modes because they reduce travel times and have lower environmental impacts (Reck et al., 2022). They are a particularly convenient transport mode for short urban trips (Gössling, 2020; Hawa et al., 2021; Reck et al., 2021) and as a viable alternative for first and last-mile trips to and from public transportation (Liazos et al., 2022; Weschke et al., 2022). For example, in cities like Athens, Zurich, and

* Corresponding author.
E-mail addresses: izquierdoe@uninorte.edu.co (E. Izquierdo-Herazo), mauricio.orozco@tecnico.ulisboa.pt (M. Orozco-Fontalvo), margareth.gutierrez@conchaytoro.cl (M. Gutiérrez), rramos4@uc.cl (R. Ramos), victor.cantillo@uninorte.edu.co (V. Cantillo).

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Berlin, e-scooters serve as a substitute for walking, a complement to public transportation (Liazos et al., 2022; Reck et al., 2022; Weschke et al., 2022) and, in some cases, as a replacement for private cars (Wang et al., 2023).

With the rise in popularity of e-scooters, concerns about public space management, user misbehavior, and road safety have become increasingly urgent (Orozco-Fontalvo et al., 2023). For instance, studies from the United States, Europe, Singapore, and Australia have shown that most injuries occur on the head and limbs due to the low use of helmets and risky behaviors like driving under the influence of psychoactive substances (Kobayashi et al., 2019; Blomberg et al., 2019; Störmann et al., 2020; Liew et al., 2020; Raubenheimer et al., 2023). Reports from the United Kingdom and Sweden indicate that 10 % to 13 % of e-scooter crashes involve other road users, highlighting the risks of improper e-scooter use in public spaces (Northway et al., 2022; Stigson et al., 2021).

The lack of restrictions on e-scooter parking can negatively affect the aesthetics of the urban environment, as these devices could become potential obstacles for pedestrians, cyclists, and drivers (Blomberg et al., 2019; Fang, 2019). There is also a growing public concern about the escalating healthcare costs of using e-scooters. It is estimated that they could reach 6 million euros annually in cities like Lisbon (Félix et al., 2023).

Despite these concerns, e-scooters often lack adequate regulations. Several authors have called for measures, such as mandatory protective gear and speed limits, to improve safety (Stigson et al., 2021). Nevertheless, these regulations could negatively impact the e-scooter market since they could make e-scooters less appealing for urban trips (Riggs et al., 2021). Moreover, the users' reaction to the adoption of public policies also depends on complex interactions between the implemented measure and the non-observable attitudes and perceptions of the potential users (Carroll, 2022). For instance, one would expect risk-averse users to be less affected by the introduction of mandatory use of helmets or speed regulations. However, comprehensive evaluations of these interactions and how they affect e-scooter demand remain scarce in the literature.

This paper fills this gap by examining how specific regulations affect the willingness to use e-scooters, considering the complex interactions between individual characteristics and perceptions of *road unsafety*. We estimate a Hybrid Choice Model (HCM) using a Stated Preference (SP) survey conducted on 645 individuals in Bogotá, Colombia. We then use the estimated model to evaluate the impact of policies such as mandatory helmet use, circulation, speed, and parking restrictions. The underlying hypothesis is that the willingness to use e-scooters is affected by the regulations and restrictions in place.

The contributions of this paper to the growing literature regarding e-scooter regulation, operations, and demand are threefold. First, we study how the adoption of specific regulations affects individual behavior and the willingness to use e-scooters. Second, we incorporate individual perceptions of road unsafety as an explanatory factor, showing how safety concerns mediate the effect of policies on demand. Thirdly, we estimate demand semi-elasticities for e-scooters under different regulatory regimes.

The rest of the paper is organized as follows: Section 2 reviews the relevant literature to understand our work's contributions. Section 3 outlines the research hypotheses. Section 4 details the methodology, including the survey design and the proposed model. Section 5 describes the data and sample statistics. Section 6 presents the main results, including the measurement model, the Hybrid Choice Model, and policy implications. Section 7 concludes the paper and offers avenues for future research.

2. Related literature

Since their recent introduction into the mobility sector, a growing number of studies have examined various topics related to e-scooters. This body of research has explored the impacts of e-scooters on urban mobility, consumer perceptions, and environmental outcomes (Badia and Jenelius, 2023; Reck et al., 2022). It has also addressed changes in travel patterns, substitution between transport modes, travel attributes, and user profiles (Hardt and Bogenberger, 2019; Wang et al., 2023). Other studies have investigated their implications for road crash rates, psychosocial risk factors of riders, methodologies for incorporating e-scooters into transport planning through demand estimation, and the externalities associated with e-scooter ridership (Useche et al., 2022; Transportation Research Board, 2022; Félix et al., 2023). Research has also considered the impact of COVID-19 on e-scooter use and proposals for defining service levels (Kazemzadeh and Sprei, 2022).[1] Nevertheless, rather than providing a comprehensive literature review, this section focuses on the relevant studies to frame this paper's contribution: (i) regulatory policies for e-scooter operations and (ii) the evaluation of perceptions regarding e-scooter operation and regulation.

Current research on e-scooter regulations employs a wide range of methodologies, including interviews, surveys, case studies, and, in some instances, specialized literature reviews (see Table 1). These analyses examine existing literature, attributes subject to regulation, and guidelines implemented globally (Bozzi and Aguilera, 2021). Another approach involves reviews specifically focused on measures applied at national or international levels (Buongiorno et al., 2022; D'andreagiovanni et al., 2022; Riggs et al., 2021). Other studies explored the relationship between issues anticipated before the operation of scooters in cities and those experienced after their introduction (Gössling, 2020), providing recommendations such as defining maximum operating speeds, mandatory use of cycling infrastructure, and dedicated parking.

Several authors incorporated primary data collection to understand the perspectives of users, non-users, and other stakeholders regarding the operation of e-scooters to derive informed policy recommendations (Latinopoulos et al., 2021; Szemere et al., 2024). Additionally, recommendations have been explored through geospatial analyses (Liazos et al., 2022) and the development of technical reports with specific proposed measures (Reinhardt and Deakin, 2020). These studies highlighted critical aspects, including infrastructure, road safety, equity policies, and legal frameworks governing shared scooter providers. They also emphasized that decision-

[1] To further explore other aspects of electric scooters, readers are advised to refer to Wang et al. (2023), Orozco-Fontalvo et al. (2023), and Liao & Correia (2022).

Table 1
Literature related to policies on the use of electric scooters.

Paper Description	City / Country	Methodology	Helmet	Infraest.	Parking	Speed	Cost	Fines	Others Policy and regulatory aspects	Perceptions	Description
Choi et al. (2022)	Jakarta (Indonesia)	ML mode, SP survey							1. Provide subsidies. 2. Construction of ES charging infrastructure		Evaluate the impact of these policies on the intention to purchase ES.
Szemere et al. (2024)	Hungary	QFD, Interview with government officials, Focus group, Questionnaire	✓	✓	✓	✓			Maximum power, Age restriction, others		Based on the evaluation, it outlines the most important aspects to regulate
Reinhardt and Deakin (2020)	California (USA)	ST. Case study, User survey, interview	✓	✓	✓	✓			Require providers to have a license, others		Proposes a series of 18 best practice policies aimed at users and service providers.
Riggs et al. (2021)	USA	Review, Official municipal websites	✓	✓		✓			Driver's license, others		Identifies policy trends for regulating ES. Focuses on pilot programs, limiting vendors, and equity policy. Provides policy recommendations
Latinopoulos et al. (2021)	Paris (France)	ST. Microsimulation, Surveys, Focus group, Big vehicle data, Expert interview		✓	✓	✓		✓	Limit the number of operators, Driver's license, others		Proposes an evaluation framework that classifies aspects of interest for planners and policymakers. Policy and regulatory implications.
Bozzi and Aguilera (2021)	–	Academic literature review, Academic databases	✓	✓	✓	✓			Legal framework, Data privacy, others		Systematic review of ES use and its users, health and environmental impacts, and policy issues.
D'Andreagiovanni et al. (2022)	Rome (Italy)	Geospatial processing. Areas reported in company apps		✓		✓		✓*	Geographic areas of operation. Limit of ES in circulation		Analyzes ES shared service. General review of regulations in Rome and guidelines in Italy
Liazos et al. (2022)	Athene (Greece)	Non-Dominated Sorting Genetic Algorithm, NSGA-II. Urban QGIS network. Random generation of travel patterns.		✓		✓					Proposes a network design model (geofence) to regulate interactions between ES drivers and other actors in urban infrastructure, and evaluates travel time impacts
Buongiorno et al. (2022)	–	Literature review. Databases, Official state websites	✓			✓		✓	Age restriction, Mandatory insurance for new vehicles		Systematic review of ES regulations in European countries, regulatory proposals.
Gössling (2020)	–	Literature review. Databases, Media		✓	✓	✓			Limit the number of operators		Investigates challenges associated with the introduction of ES in large cities and proposes recommended policies
Lo et al. (2020)	New Zealand	Statistical processing of surveys. SP survey	✓	✓	✓	✓			Discount scheme		Analyzes the frequency of use of the shared system in the face of regulatory incorporation
Sobrino et al. (2023)	Spain	Disparity index, consensus criteria. Survey, Focus group	✓		✓	✓			Area of operation, Equity, Travel monitoring, others		Addresses points of consensus and non-consensus on regulations among stakeholders. Offers regulatory recommendations
Dias at al (2024)	Braga (Portugal)	Statistical processing of instrument. RP survey	✓	✓	✓	✓	✓	✓	Influence of regulations	✓	Evaluate how university students perceive e-scooter as a sustainable mode
This paper	**Bogotá (Colombia)**	**HCM. Survey**	✓	✓	✓	✓	✓	✓		✓	**Studied how regulations affect the willingness to use e-scooters, considering individual characteristics, and perceptions.**

* Fines to operators of shared electric scooter services.
ES: Electric Scooters. QFD: Quality Function Deployment. ML: Logit Mixto. HCM: Hybrid Choice Model. SP: Stated Preferences.

makers must implement policies guiding vehicle operation and user behavior.

Discrete choice analysis has emerged as a tool to support policy formulation in shared mobility systems, facilitating the estimation of travel behavior and quantifying determining factors (Luo et al., 2023). An illustrative example is found in the study by Kim et al. (2023), who implemented a binary model to evaluate mode substitution by incorporating e-scooters into the mobility landscape. Likewise, Carroll (2022) used a binary model to explore the sociodemographic and travel characteristics influencing mode choice in Dublin, revealing that time and comfort are the two predominant factors in this choice.

Multinomial Logit (MNL) models have been used to analyze transport mode choice in the micro-mobility sector (Reck et al., 2021), as well as the influence of motivational aspects on the choice of shared e-scooters (Weschke et al., 2022). Tuli et al. (2021) contributed to the field by developing a Random Effects Negative Binomial (RENB) model to estimate the impact of temporal and independent variables on the demand for shared scooters.

Nevertheless, there is a significant gap in the literature regarding the impact of regulations on the intention to use e-scooters. To the best of our knowledge, only two papers have studied this topic. Choi et al. (2022) employed a Mixed Logit model to estimate the impact of subsidies and charging infrastructure on the willingness to pay for moped e-scooters. Lo et al. (2020), on the other hand, aimed to understand the effects of operational regulations on the frequency of use of shared electric scooter systems; however, the study took an aggregated approach, limited to statistical analysis without applying a specific model. Thus, neither of these studies considered individual behaviors in detail or incorporated individual variables, regulatory attributes, and personal perceptions.

Another branch of the literature have evaluated individuals' attitudes and perceptions toward e-scooters (Table 2). Not surprisingly, road safety is the most commonly studied latent variable in the context of e-scooter usage (Kopplin et al., 2021; Luo et al., 2023; Guo et al., 2023; Nikiforiadis et al., 2021; Orozco-Fontalvo et al., 2025). This focus arises from documented crashes and falls in cities with e-scooter operations, which have raised safety concerns among scholars and policymakers (Che et al, 2021; Félix et al., 2023; Haworth et al., 2021).

Another latent variable explored in prior research is the environmental concern among potential users (Kopplin et al., 2021; Luo et al., 2023; Orozco-Fontalvo et al., 2025), as e-scooters are often viewed as a sustainable mode of transportation (Öztaş Karlı et al., 2022; Kopplin et al., 2021).

Regarding methodology, Structural Equation Models (SEM) have been widely used to study e-scooter adoption, incorporating latent constructs related to road safety, social influence, environmental concern, effort, performance expectancy, and privacy concerns (Kopplin et al., 2021; Samadzad et al., 2023; Chen and Lee, 2023; Orozco-Fontalvo et al., 2025). Hybrid choice and latent variable models have also been developed (Luo et al., 2023; Guo et al., 2023; Nikiforiadis et al., 2021). However, these studies have only included trip characteristics and modal attributes as determinants of individual choice, excluding policy attributes from the analysis.

In summary, there are three gaps in the literature regarding the regulatory framework of e-scooters. Firstly, previous works overlooked the impact of regulations and restrictions on the willingness to use e-scooters. Secondly, only Choi et al. (2022) have acknowledged the discrete nature of the demand for e-scooters when evaluating the impact of regulatory policies; however, they do not consider the role of individual perceptions. Thirdly, although of *road unsafety* perceptions influence e-scooter usage, no previous work has incorporated this dimension into the analysis of e-scooter regulations. This paper aims to fill this gap by acknowledging the relationship between regulatory policies and the intention to use e-scooters through a Hybrid Choice Model.

3. Research hypotheses

Previous research has found mixed results regarding implementing restrictions on the operation of e-scooters. For instance, Lo et al. (2020) suggest that regulations negatively affect the use of shared scooters. However, Latinopoulos et al. (2021) found that the presence of bike lanes positively affects perceptions of safety among non-users, and that e-scooter owners are more likely to wear helmets than infrequent users of shared systems. Distinct behavioral patterns have emerged in response to speed restrictions. Riders of high-powered scooters who travel alongside cars on the road are generally reluctant to accept a speed limit below 25 km/h. In contrast, occasional users of shared e-scooters riding on sidewalks or bike lanes would not mind a lower speed limit (Szemere et al., 2024). Considering the above, the following research hypotheses are formulated:

H1: Speed restrictions, mandatory helmet use, and parking regulations are associated with a lower intention to use e-scooters.

Regarding regulations, Lo et al. (2020) found that regulations targeting rider behavior tend to decrease shared scooter usage. Evidence from other contexts, such as cycling in Australia, suggests that such requirements may lead people to see micromobility options as unsafe or inconvenient, which can reduce ridership (Gerhard, 2023; Hoye, 2018). This perception may be especially relevant for occasional riders, who are less likely to carry helmets.

Parking regulations have also been linked to reduced use of shared e-scooters. Buehler et al. (2022) reported a 72 % decline in ridership following the introduction of mandatory parking corrals. Similarly, using an agent-based model, Hurlet et al. (2024) showed that requiring users to walk longer distances to reach designated parking areas can discourage use. Moreover, although some users may appreciate the order that designated parking brings, others may view these rules as restrictive, especially for short or spontaneous trips (Siebert et al., 2021).

H2: Restrictions on riding infrastructure are associated with a preference for exclusive circulation on bike lanes when using e-scooters.

Overall, e-scooter users prefer infrastructure that separates them from general traffic. Gioldasis and Christoforou (2021) found that users feel safer on cycle lanes and sidewalks compared to shared lanes with buses, taxis, or mixed traffic. Pazzini et al. (2022) reported that 60–90 % of users favor cycle paths and other separated facilities. Similarly, Sievert et al. (2023) noted that over 60 % of riders consider protected bike lanes the safest option. Other studies show that e-scooter users are more likely to use bike lanes when available,

Table 2
Literature related to perceptions and attitudes.

Paper	Country	Survey	Methodology / Model	Policies	Road Safety	Hedonic	Performance	Effort	Environmental concern	Others	Evaluated Aspect
Kopplin et al. (2021)	Germany	SP	UTAUT2 / PLS-SEM		✓	✓	✓	✓	✓	Social influence, others	Intention to use vs Current use
Samadzad et al. (2023)	Iran	SP	Extended TAM / PLS-SEM			✓			✓	Social influence, Trust, others	Intention to use
Luo et al. (2023)	Indianapolis (USA)	SP	ICLV based on CNL		✓*				✓	Social image, others	Modal choice
Chen and Lee (2023)	Taiwan	SP	SEM			✓				Service quality, Civility, others	Service quality and value
Guo et al. (2023)	Beijing (China)	SP	ICLV-NL		✓*				✓*	Social benefits, others	Integration of PT and DBS
Roig-Costa et al. (2024)	Barcelona (Spain)	Open survey	Binary logistic regression							Satisfaction, reasons for mode choice	Difference between actors and modal choice
Lee et al. (2021)	Seoul (Korea)	SP	Latent class ordinal logit and adjacent category							Satisfaction with public transport	Intention to use
Nikiforiadis et al. (2021)	Thessaloniki (Greece)	SP	Latent variable logit		✓					Infrastructure, connection with other modes	User profile
Orozco-Fontalvo et al (2024)	Bogotá (Colombia)	SP	SEM-MIMIC		✓	✓			✓	Crime	Current use
This paper	**Bogotá (Colombia)**	**SP**	**Latent variable hybrid based on binary logit**	✓	✓	✓		✓			**Intention to use**

*The perception is not included as a latent variable, but as an indicator.
UTAUT2: Unified Theory of Acceptance and Use of Technology. PLS-SEM: Partial Least Squares Structural Equation Modeling. TAM: Technology Acceptance Model. ICLV: Integrated Choice and Latent Variable Model. CNL: Cross-Nested Logit. NL: Nested Logit. TPB: Theory of Planned Behavior. TP: Public Transport. DBS: Dockless Bike-Sharing. SEM-MIMIC: Structural Equation Modeling – Multiple Indicator Multiple Cause.

leading to reduced use of sidewalks and shared lanes (Neshagaran et al., 2024; Cicchino et al., 2024). This behavior is consistent across cities and shaped by both safety and convenience. Riders also place importance on road surface quality, with bike lanes offering smoother rides and fewer conflicts with cars and pedestrians (Ringhand et al., 2024).

H3:. Higher costs for shared services and the inclusion of fines for infractions are associated with a lower intention to use e-scooters.

Several studies show that users are highly responsive to cost. In Singapore, higher fares were found to reduce e-scooter modal share (Cao et al., 2021). Research in Germany and Serbia also identified travel cost as a key factor in mode choice decisions, with an impact comparable to travel time (Krauss et al., 2022; Glavić et al., 2023). While some users may be more open to paying for convenience (Carroll, 2022), higher costs generally act as a barrier to broader adoption.

Beyond rental fees, the inclusion of fines for misconducts may also discourage e-scooter use. Financial penalties and strict enforcement can deter those more likely to engage in risky behaviors (Alexander and Bates, 2024; Oh et al., 2024). Fines raise the perceived cost of using the service, especially if users expect enforcement to be frequent (Ramos and Silva, 2023). This can lead to a decline in ridership, particularly among occasional or less compliant users.

H4*:* Road unsafety perception is positively associated with the approval of regulations on e-scooters.

Regarding Road unsafety, concerns about accidents and injuries have contributed to increased public support for policies aimed at improving safety (Piatkowski et al., 2024; Wallgren et al., 2023). These concerns are often shaped by media reports and personal experiences, which can reinforce the idea that e-scooters are unsafe. People who view e-scooters as risky —particularly non-users— are more inclined to favor regulations such as speed limits, helmet requirements, and restricted riding zones (Wallgren et al., 2023; Pourfalatoun et al., 2023).

Perceptions of safety are not uniform across all groups. Older adults and women, who often feel more exposed in traffic, are generally more supportive of additional regulations (Kazemzadeh, 2025; Dias et al., 2024). On the other hand, individuals who are already familiar with using e-scooters and who feel more at ease while riding may be less supportive of such measures (Sievert et al., 2023).

H5: *Road unsafety* perception is negatively associated with the intention to use electric scooters.

On the one hand, riders who perceive the streets as unsafe often change their travel behavior, avoiding routes they consider dangerous (Tzouras et al., 2023). This can reduce the flexibility and convenience e-scooters are intended to offer. Experiences with crashes or near misses may shift users' views from seeing e-scooters as enjoyable to seeing them as risky, which discourages continued use (Piatkowski et al., 2024). Fear of collisions or crime is also associated with lower usage, particularly when riders must share the road with faster vehicles (Orozco-Fontalvo et al., 2025; Oh et al., 2024).

4. Methodology

4.1. Survey design

Based on the literature presented in section 2, we first identified which regulations and perceptions may influence the intention to use e-scooters. This information was used to construct the indicators of perceptions and the variables related to e-scooter regulation to be included in the choice experiment. The survey was designed to explore how public policies, perceptions, and sociodemographic attributes influence the willingness to use e-scooters. The instrument consists of three sections: the first gathers respondent attributes; the second asks about perception constructs; and the third presents hypothetical choice scenarios with different regulatory combinations, where respondents choose whether they would use e-scooters.

In the first section, sociodemographic attributes such as age, gender, occupation, educational level, and household socioeconomic strata are collected. In Colombia, socioeconomic stratification is a classification system designed to assign subsidies for public services. Cantillo-García et al. (2019) showed that it is highly correlated with household income. Strata 1 and 2 correspond to low-income households, 3 and 4 indicate middle-income, and 5 and 6 represent high-income. Consequently, it has been used in Colombia as a proxy variable for household income (e.g., Chica-Olmo et al., 2020; Gutiérrez et al., 2021; Paba-Larios et al., 2025).

The survey also asks about the number of bicycles, motorcycles, and cars in the household, the current primary mode of transport, and whether the respondent has used e-scooters. For users, additional questions include whether the vehicle is owned or rented, the type of trip made (complete or complementary), and the preferred substitute mode if the scooter is unavailable.

The second stage of the survey incorporates constructs affecting the intention to use e-scooters. Individuals were asked to state their level of agreement with a set of indicators related to e-scooters perception, using a Likert scale ranging from one (strongly disagree) to

Table 3
Latent variable and indicators used.

Latent variable	ID	Indicator	Source
Road Unsafety	RU1	Using electric scooters on city streets is dangerous.	a*, b*
	RU2	If I use an electric scooter, I have a high probability of having an accident.	a*, b*
	RU3	Electric scooters are more dangerous than bicycles.	
	RU4	Cars and motorcycles do not consider electric scooter users.	
	RU5	Electric scooters are a risk for pedestrians.	c*

Adapted from a: Kopplin et al., 2021; b: Samadzad et al., 2023; c: Nikiforiadis et al., 2021.
* The indicator from the cited article serves as a guideline.

five (strongly agree), presented in Table 3. These indicators were designed to capture individuals' subjective perceptions of the risk and lack of safety associated with riding e-scooters.

The survey included latent constructs related to the individuals' perceptions of *road unsafety*, *hedonic motivation*, and *effort expectancy*. However, a CFA analysis shows that only the *road unsafety* construct meets conventional reliability and validity tests. This latent construct is well-established in the literature and has been validated in previous studies (Daziano and Rizzi, 2015; Rossetti et al., 2018;). Importantly, perceptions of *road unsafety* have been examined not only for e-scooter users but also for other vulnerable road users such as pedestrians and cyclists (Márquez and Soto, 2021; Gutiérrez et al., 2025), where concerns about traffic conflicts, inadequate infrastructure, and exposure to motorized vehicles have been consistently highlighted (Sanders, 2015; Nikiforiadis et al., 2021). Moreover, safety issues are the main negative impact of e-scooters, surpassing the potential benefits (Félix et al. 2023). Building on this literature, we adapted a set of indicators (see Table 3) to the local context of Bogota in order to analyze how safety perceptions interact with regulatory policies and affect the willingness to commute by e-scooters.

The Stated Preference (SP) survey presented respondents with nine scenarios in which they were asked whether they would use e-scooters for their daily commute, imagining the trip could be completed in approximately 15 min. Each scenario featured specific combinations of regulatory policies for e-scooters, including helmet use, riding infrastructure, parking mode, speed restrictions, travel cost, and fines for infractions. Each restriction had three levels, except for "helmet use," which had two, as shown in Table 4. These attributes were selected based on the literature reviewed in Section 2. An orthogonal design of 36 choice scenarios was developed and distributed across four blocks; consequently, each respondent was presented with nine choice scenarios.

Shared e-scooter services typically use a two-part tariff scheme with a fixed base fee and an additional charge per minute. For example, in Bogotá, a well-known company had a pricing scheme that charged USD 0.40[2] to unlock the scooter and USD 0.08 per minute. However, to facilitate the comprehension of the survey, instead of presenting the full pricing scheme, the survey presented the total cost for a typical 15-minute trip (approximately USD 1.25 using the above values). Fig. 1 shows a choice scenario presented to respondents.

4.2. Proposed model

The impact of policies regulating e-scooters on the intention to use them is evaluated through a Hybrid Choice Model (HCM), which incorporates the latent variable together with observable individual characteristics, operational attributes and regulatory measures related to e-scooters.

Individuals' perceptions are not directly measurable, so they are included in the model as latent variables Z_{lq}, which depend on the observable individual characteristics of the respondents Y_q through structural equations (Márquez et al., 2020). This configuration is shown in Eq. (1), where *q* refers to an individual, *l* to a latent variable, and ω_{lq} constitutes a random error term (Gutiérrez et al., 2020, 2021; Walker, 2001).

$$Z_{lq} = h(Y_q; \lambda) + \omega_{lq}. \tag{1}$$

In turn, it is assumed that the variables Z_{lq} and a random error term ν_{pq} explain the indicators I_{pq} (where *p* refers to the indicator) through measurement equations (2):

$$I_{pq} = m(Z_{lq}; \alpha) + \upsilon_{pq}. \tag{2}$$

An ordinal logit model is incorporated to represent the different response categories of the indicators, where each categorical response *j* in the indicator I^*_{pq} is defined by a set of threshold parameters τ to be estimated (Daly et al., 2012; Greene, 2012; Márquez et al., 2020).

$$I^*_{pq} = \{1 if -\infty < I_{pq} \le \tau_{p1}, 2 if \tau_{p1} < I_{pq} \le \tau_{p2,} \cdots J if \tau_{p(j-1)} < I_{pq} \le \infty. \tag{3}$$

In this way, the HCM incorporates the attributes of the choice situations related to regulatory policies and the latent variables representing perceptions in the utility function for each alternative *i,* as shown in Eq. (4), where the error term ε_{iq} is assumed to be IID Gumbel.

$$U_{iq} = \beta_l Z_{lq} + (\theta_i + \delta_k \widehat{Z}_{lq}) X_{iq} + \varepsilon_{iq} \tag{4}$$

In this case, the discrete choice submodel is binary, as individuals choose whether or not they would use the e-scooter under specific scenarios. Therefore, the utility of using the e-scooters has the functional form presented in Eq. (4), while we normalize the systematic utility of not using the e-scooter to zero. In this specification, we also incorporate interaction terms between the attributes X_{iq} and a subset of latent variables (denoted by $\widehat{Z}_{lq}$) to capture how these contextual factors affect individuals' perceptions and influence their utility for e-scooter use. These interaction effects are represented by the parameters δ_k in the equation. The parameters λ, α, θ, τ, *δ,* and β are estimated simultaneously using simulated maximum likelihood through the Apollo R package (Hess and Palma, 2019).

Before estimating the HCM, a Confirmatory Factor Analysis (CFA) was conducted to verify that the grouping of indicators corresponds appropriately with the proposed latent variable. This configuration is then incorporated into the HCM.

[2] At the time the survey was conducted, 1 USD was approximately 3,900 COP.

Table 4
Level of attribute restrictions.

Restriction	Levels			Source
	0	**1**	**2**	
Helmet use	Not mandatory	Mandatory	–	(Haworth et al., 2021) (Peters and MacKenzie, 2019)
Riding infrastructure	No restriction	Only on bike lanes	On bike lanes or the road	(Zuniga-Garcia et al., 2021) (Lanza et al., 2022)
Parking mode	Can leave the scooter anywhere	Must take the scooter to designated stations	Can leave the scooter anywhere for an extra cost or at designated stations	(Peters and MacKenzie, 2019)
Speed restriction	No restriction	Maximum 20 km/h	Maximum 25 km/h	(Che et al, 2021)
Travel cost	4,000COP	5,000COP	6,000COP	
Fines for infractions	No fines	150,000COP	250,000COP	

In the following scenario, would you use the electric scooter?

Helmet use	Not mandatory
Circulation infrastructure	On bike lanes or the road
Parking mode	Must take the scooter to designated stations
Speed restriction	Maximum 25 km/h
Travel cost	5,000COP
Fines for infractions	250,000COP

Mark only one response

- *Yes*
- *No*

Fig. 1. Example of a choice situation.

5. Data description

5.1. *Case study*

We applied the survey in Bogotá, in the first quarter of 2022. Bogotá is the capital of Colombia, with approximately 8 million inhabitants, according to the 2018 census (DANE, 2018). The city is the center of a larger metropolitan area, including municipalities such as Soacha, Chía, and Mosquera, with a population of over 10 million. Bogotá is a main destination for daily commute, due to the concentration of jobs, educational institutions, and government offices.

On a typical day, approximately 14.6 million trips are made across the metropolitan area, of which a significant proportion (approximately 35 %) are made in public transport (Secretaría Distrital de Movilidad de Bogotá, 2024). The city has a network of 500 km of bike lanes, known as *ciclorutas*, making it one of the most extensive cycling infrastructures in Latin America. Hence, 7 % of daily trips are made by bicycle (Márquez et al, 2024). According to the latest data, 12,700 daily e-scooter trips were made in 2023 (Secretaría Distrital de Movilidad de Bogotá, 2024) with an average trip distance for this mode of 2.2 km, and the average speed was 16.7 km/h.

To regulate the use of e-scooters, Bogotá introduced specific zones where rentals are permitted, as shown in Fig. 2. These zones are outlined in Circular N° 011 of August 5, 2019, issued by the Secretaría Distrital de Movilidad de Bogotá (2019). They define the authorized public spaces for scooter rentals and parking areas designated by the rental company Grin.

The demographic profile of e-scooter users in Bogotá, along with the characterization of our survey sample, is presented in Table 5.

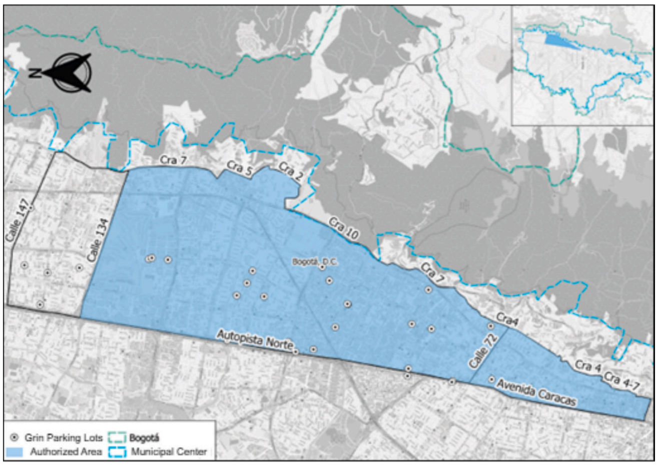


Fig. 2. Authorized zone and stations for scooter rentals.

There is a preponderance of males, young people, and middle and high-income groups. This tendency is consistent with international studies, which also show that e-scooter users are predominantly male and tend to have higher education levels (Nikiforiadis et al., 2021; Dott, 2022; Useche et al., 2022). These studies suggest that *unsafety perception* and lack of dedicated infrastructure, like protected bike lanes, may discourage female users. At the same time, the association of e-scooters with higher income could explain the higher representation of university graduates.

5.2. Descriptive statistics of the sample

Surveys were conducted using an intercept approach, targeting residents from various city areas, especially in universities, shopping centers, streets in high-income sectors, and areas where electric scooter stations are usually located. The survey was shared through QR codes. Participation was ensured only for citizens or people who commute daily in Bogotá. Respondents were offered assistance in filling it out if required.

Columns 3–5 of Table 5 summarize the sociodemographic profile of the respondents, while column 6 summarizes the profile of the e-scooter users in Bogotá (Secretaría Distrital de Movilidad de Bogotá, 2024). A total of 645 valid surveys were obtained. Most respondents were non-users of electric scooters (62 %). Also, notice that although there is a slight majority of female respondents (53 %), those who use e-scooters are mainly male (61 %), which is consistent with Latinopoulos et al. (2021) and the profile of the e-scooter users in Bogotá (68 %).

The surveyed users' profile is characterized by young men from the middle socioeconomic strata and primarily students or employees with either a professional degree or pursuing university studies. This profile shares similarities with the findings of Carroll (2022), Bozzi and Aguilera (2021), and Badia and Jenelius (2023), although the latter reported higher-than-average incomes.

Most respondents in our sample are under 40 years old (85 %), which aligns with the demographic profile commonly associated with e-scooter users, as noted in previous studies (Department of Transportation, 2019; Fitt and Curl, 2019; City of Calgary, 2020; Los Angeles Department of Transportation, 2020; 6t-bureau de recherche, 2019; City of Santa Monica, 2019). However, we recognize that our sample may overrepresent younger individuals, who account for 65 % of e-scooter users in Bogotá (Secretaría Distrital de Movilidad de Bogotá, 2024).

Conversely, our sample may underrepresent high-income users, who make up 37 % of current e-scooter users, compared to only 7.8 % in our sample. Additionally, 42 % of respondents are university students, which could further indicate an overrepresentation of this group. As a result, our findings primarily reflect the perceptions and preferences of younger, mid-income students, potentially limiting the transferability and generalizability of our results to other demographic groups.

Overall, 75 % of the respondents have one car or less, two bicycles or less, and one motorcycle or less in their household. Additionally, a significant portion reported public transportation as their primary mode of transport (36 %), followed by e-scooters and private vehicles. Among scooter users, 79 % rent the vehicle, while 21 % own one. Similarly, the typical trip is mainly complementary (65 %), and bicycles are preferred as an alternative mode if an electric scooter is unavailable (23 %), followed by public transportation

Table 5
Sociodemographic Profile of E-Scooter Users: Survey Sample and General Bogotá Population.

Variable	Level	Survey participants (n = 645)			E-scooter users in Bogotá*
		Non User (n = 400)	User (n = 245)	Total sample (n = 645)	
Sex	Female	61.5 %	38.8 %	52.9 %	32 %
	Male	38.5 %	61.2 %	47.1 %	68 %
Age	16–19	18.5 %	14.3 %	16.9 %	6 %
	20–29	44.5 %	72.7 %	55.2 %	14 %
	30–40	14.0 %	10.6 %	12.7 %	48 %
	41–50	13.0 %	1.6 %	8.7 %	25 %
	51–77	10.0 %	0.8 %	6.5 %	7 %
Socioeconomic strata	Low	29.5 %	22.4 %	26.8 %	10 %
	Medium	67.3 %	69.8 %	68.2 %	53 %
	High	3.3 %	7.8 %	5.0 %	37 %
Education level	Preschool and Primary	0.8 %	0.4 %	0.6 %	–
	High school	18.8 %	14.3 %	17.1 %	–
	University student	34.5 %	54.3 %	42.0 %	–
	Technician-Technologist	15.3 %	9.8 %	13.2 %	–
	University Degree	20.3 %	16.3 %	18.8 %	–
	Postgraduate	10.5 %	4.9 %	8.4 %	
Occupation	Housewife	3.0 %	1.2 %	2.3 %	–
	Merchant	0.3 %	0.0 %	0.2 %	–
	Unemployed	1.5 %	0.4 %	1.1 %	–
	Employee	30.0 %	27.8 %	29.1 %	–
	Student	46.8 %	60.4 %	51.9 %	–
	Self-employed	15.5 %	9.4 %	13.2 %	–
	Retirees	3.0 %	0.8 %	2.2 %	–

*Secretaría Distrital de Movilidad de Bogotá, 2024.

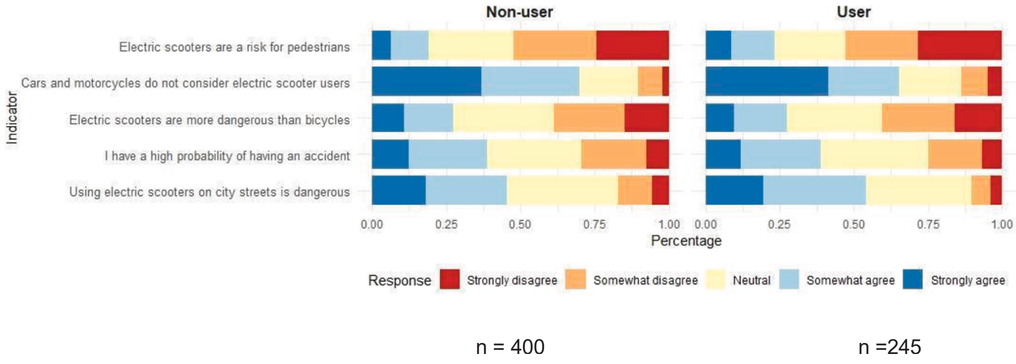


Fig. 3. Responses to *road unsafety* indicators.

(20 %) and motorcycles (18 %).

6. Estimation results

6.1. Measurement model and indicators analysis

Before assessing the validity of the construct through a confirmatory factor analysis (CFA), we first examined the distribution of responses to the five survey indicators of *road unsafety* (Fig. 3). The descriptive results show that both users and non-users of e-scooters express similar concerns about safety. Approximately two out of three respondents believe that motorized vehicles do not respect e-scooter users, and half consider riding e-scooters on city streets to be dangerous.

Around 40 % of respondents perceive a high probability of being involved in a traffic crash while using an e-scooter. However, they do not believe e-scooters are more dangerous than other modes of transport. Finally, nearly half of the respondents consider riding e-scooters on city streets unsafe. This perception may stem from how respondents view interactions with motorized vehicles, as about half believe e-scooters do not pose a risk to pedestrians.

While these descriptive results provide an overview of how respondents perceive road unsafety, it is necessary to validate whether the survey indicators consistently represent a single underlying construct. To this end, we conducted a CFA on the construct *road unsafety*, initially measured with five indicators (RU1-RU5). In line with common thresholds (Hair et al., 2019), factor loadings above 0.50 are considered acceptable, while Cronbach's alpha and Composite Reliability (CR) values above 0.70 indicate satisfactory internal consistency.

The CFA results revealed that three indicators (RU1, RU2, and RU3) showed satisfactory standardized loadings (0.678, 0.875, and 0.622, respectively). In contrast, RU4 and RU5 exhibited low loadings (0.273 and 0.464), below the recommended cutoff, and were therefore excluded from the final specification of the latent construct (Hair et al., 2019, p. 151). Table 6 reports the retained indicators and their measurement properties. With these three items, the construct achieved acceptable internal consistency (Cronbach's alpha = 0.726; CR = 0.773), and the Average Variance Extracted (AVE) was 0.537, exceeding the recommended threshold of 0.50. Together, these results support the reliability and convergent validity of the measurement. As only one latent construct was included in the model, discriminant validity is not applicable in this study.

6.2. Hybrid choice model

We tested different specifications in the utility function and the structural equations of the latent variable and explored alternative approaches, such as representing individual heterogeneity with a Mixed Logit model. We compared models using the likelihood ratio test, the corrected rho-square index, and the sign and significance levels of the policy variables.

To assess the contribution of the latent construct, we estimated two models: a baseline specification without latent variables and a HCM incorporating *road unsafety*. The comparison indicates that the HCM provides a better fit (Table 7). According to the likelihood ratio (LR) test, the hybrid model specification is superior. In particular, the inclusion of *road unsafety* captures attitudinal heterogeneity that cannot be explained solely by observable characteristics, improving both the explanatory power and behavioral realism of the model. This result highlights the importance of considering safety perceptions when evaluating the effectiveness of regulatory policies.

Fig. 4 presents the schematic of the best-performing model, an HCM that incorporates the latent variable *road unsafety*. This latent variable is explained by the individual's sociodemographic variables in the model's structural equations Eq. (1). At the same time, the

Table 6
Summary of the measurement model.

Latent variable	ID	Factor loading	Alpha Cronbach	CR
Road Unsafety	RU1	0.678	0.726	0.773
	RU2	0.875		
	RU3	0.622		
	RU4	*0.273**		
	RU5	*0.464**		

* Indicator was removed from the final construct and was not considered when estimating Cronbach's alpha or Composite Reliability (CR).

Table 7
Estimated parameters and *t*-test for the HCM.

Attribute	ML-Panel effect	HDC
Utility Function	**Parameters (*t*-test)**	**Parameters (*t*-test)**
Alternative Specific Constant	1.041 (4.91)	1.050 (4.84)***
Mandatory Helmet use	0.741 (11.41)	0.758 (10.80) ***
Circulation restrictions		
Only on bike lanes	0.187 (2.44)	0.199 (2.52)**
On bike lanes or the road	0.413 (5.42)	0.415 (5.43) ***
Parking restrictions		
Must take the scooter to designated stations	−0.244 (−3.18)	−0.245 (−3.19) ***
Can leave the scooter anywhere for an extra cost or at designated stations	−0.178 (−2.36)	−0.177 (−2.32) **
Maximum speed		
20 km/h	0.075 (1.00)	0.075 (0.99)
25 km/h	0.095 (1.25)	0.094 (1.24)
Cost#	−0.257 (−6.75)	−0.260 (−6.82) ***
Fine&	−0.033 (−10.81)	−0.033 (−10.83) ***
Pseudo-panel Effect	0.890 (20.86)	0.886 (20.78) ***
Latent Variable		
Road Unsafety	–	−0.322 (−3.86) ***
Interactions		
Mandatory Helmet – Road Unsafety	–	0.193 (2.44) **
Only on bike lanes – Road Unsafety	–	0.134 (1.65)
Structural Equations		
Road Unsafety		
Age $\leq$ 20 years	–	−0.459 (−2.85) ***
21 $\leq$ Age $\leq$ 29 years	–	−0.180 (−1.37)
30 $\leq$ Age $\leq$ 40 years	–	−0.249 (−1.47)**
Number of bikes	–	0.067 (1.49)**
Car user	–	0.410 (3.14)***
Log Likelihood	–	−6184.1
Log Likelihood Choice Component	−3563.66	−3552.57
ρ^2	0.105	0.108

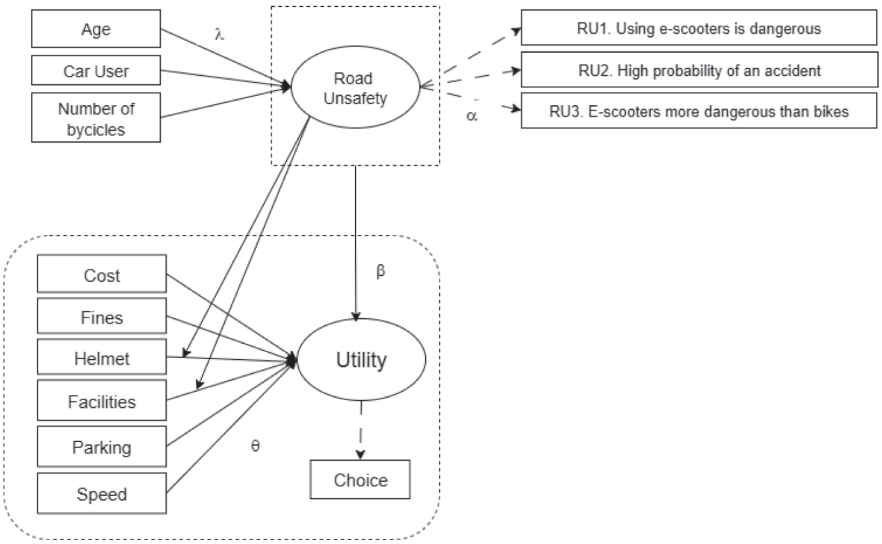
***p-value < 0.01, **p-value < 0.05, *p-value < 0.1.
Values in thousands of COP (1/1,000).
& Values in tens of thousands of COP (1/10,000).
LR = 22.18 > 7.815.

latent variable explains the perception indicators described in Table 3 via measurement equations Eq. (2).

The estimated parameters of the two models and their corresponding *t*-test results and p-values are presented in Table 7.[3] All policy attributes but the maximum speed are significant. However, we keep this variable in the model since it has the correct sign and is a relevant policy variable. Similarly, all latent variables are statistically significant in the choice model.

An important attribute of shared e-scooter services is the parking policy. On the one hand, restricting parking by limiting the placement of these devices to designated stations has a notable negative impact on the attractiveness of dockless shared e-scooter systems. Conversely, allowing parking anywhere for an extra cost has a negative but lesser effect since it offers greater freedom than the more restrictive policy. This unfavorable perception aligns with Szemere et al. (2024), who found that if it were not mandatory to park the devices in specific places, users would not do so, or if they did, they would stack them on top of each other, which is not visually appealing and causes the scooters to break down and reduce their lifespan. Interestingly, while speed restrictions were expected to lead to a lower intention, they are not significant in our model. This result differs from Lo et al. (2020) and reflects that speed restriction does not deter e-scooter usage.

[3] Table 7 presents the results of the choice component and the structural equations of the HCM. The estimated parameters of the measurement equations are available in the online appendix of this paper.



*Full arrows represent causal relationships between constructs, as supported by theoretical and empirical evidence. Dashed arrows, on the other hand, represent measurement relationships between observed variables (indicators) and unobservable latent variables.

Fig. 4. Schematic of the final HCM. *Full arrows represent causal relationships between constructs, as supported by theoretical and empirical evidence. Dashed arrows, on the other hand, represent measurement relationships between observed variables (indicators) and unobservable latent variables.

Based on these results, we now evaluate the proposed hypotheses. First, it is interesting to find that, contrary to what was expected in hypothesis **H1**, the mandatory use of helmets has a significantly positive impact on the intention to use e-scooters. This result aligns with Szemere et al. (2024) and Lo et al. (2020), who reported that protective equipment for riding e-scooters is essential for road safety and risk perception for both users and non-users.

As proposed in hypothesis **H2**, restricting the circulation of e-scooters to bike lanes positively impacts the intention to use electric scooters. This result is in line with Zuniga-Garcia et al. (2021), who state that bike lanes increase riding safety (Latinopoulos et al., 2021). Also, notice that restricting the circulation to bike lanes and roads positively affects the intention to use e-scooters. This may occur because users perceive that e-scooters should not be allowed to circulate on sidewalks and other pedestrian spaces.

In line with the economic theory, the cost associated with the shared service and the value of the fine significantly impact the intention to use e-scooters. Hence, confirming hypothesis **H3**. This result, although evident, has profound policy implications since it is crucial to establish e-scooter pricing. It is also essential to define the set of fines and the corresponding deterrence and enforcement measures to avoid e-scooter users' misbehavior (Ramos and Silva, 2023).

The model results for the direct effect of individuals' perceptions of *road unsafety* support hypothesis **H5**, as a higher perception of *road unsafety* is associated with a lower willingness to use e-scooters. However, there is a positive interaction between the perception of *road unsafety* and the adoption of regulations on helmet use and bike lane circulation. The positive signs of these interactions indicate that such regulations mitigate the adverse effect of *road unsafety* on the willingness to use e-scooters. In other words, although some users may continue to perceive e-scooters as unsafe, implementing measures aimed at improving road safety would address these concerns and encourage their use. Furthermore, the positive signs of these interactions suggest that the higher the perception of *road unsafety*, the greater the positive impact of safety-oriented policies, which supports hypothesis **H4**. These findings align with those of Szemere et al. (2024) and Latinopoulos et al. (2021).

Regarding the determinants of individuals' perceptions, age is revealed as a determining factor in concerns about road safety, showing a significant increase as age increases. Another relevant finding is the relationship between the number of cars available in the household and the concern for road safety. This relationship suggests a correlation between vehicle availability and a higher risk perception in electric scooters.

To quantify the impact of regulatory policies, we compute demand semi-elasticities of the variables associated with each policy. In

Table 8
Elasticities of e-scooter demand.

Elasticity		**Variation in Probability Use According to Policy (semi-elasticity)**				
		Mandatory helmet	Infrastructure circulation		Parking	
Cost of use	Fine		Only bike-lane	Bike-lane and road	Designated stations	Designated stations or extra cost
−0.51	−0.17	34.30 %	7. 63 %	17. 37 %	−9.32 %	−6. 79 %

this case, where all policy variables are dummies, the semi-elasticity effects represent the percentage change in the willingness to use an e-scooter when the value of the policy variable changes from 0 to 1, ceteris paribus. Table 8 shows the resulting semi-elasticities together with the price and fine elasticity, which, as usual, is interpreted as the percentage change in demand due to a percentage increase in the price or the fine.

The mandatory helmet policy has the highest positive impact on the intention to use e-scooters, increasing the probability of use by 34.30 %. Similarly, the willingness to use e-scooters is 17.37 % higher when scooter circulation is restricted to bike lanes and roads. As expected, parking restrictions negatively affect demand, potentially decreasing it by 9.32 % if parking is allowed only at designated stations and by 6.79 % if free parking is permitted at an extra cost. As expected, the price and fine elasticities are negative. Increasing the price or the fine by 10 % decreases the probability of using electric scooters by 5.1 % and 1.7 %, respectively, suggesting an inelastic price demand.

6.3. Policy recommendations

The results suggest that helmet regulations positively influence the intention to use e-scooters. However, previous research on biking preferences indicates that such regulations could deter biking (Kraemer, 2016; Hoye, 2018) and may lead to unintended consequences, such as biased enforcement and police-initiated conflicts (Mitchell and Ridgeway, 2018; Campbell, 2021). Additionally, helmet usage remains low despite safety concerns (Bozzi and Aguilera, 2021; Buongiorno et al., 2022). To address these issues, persuasive measures and awareness campaigns are recommended, particularly targeting older individuals.

Helmet use is also less frequent among users of shared services compared to those with personal vehicles (Latinopoulos et al., 2021), as carrying a helmet for spontaneous trips is inconvenient. Measures such as helmet giveaways and free helmets provided by operators are commendable (National Academies of Sciences, Engineering, and Medicine, 2023a, b,). Including helmets in rental services through agreements with providers is also advisable to promote usage among infrequent users.

We have shown that individuals with a high perception of e-scooter unsafety are more likely to use these devices when restricted to bike lanes. Previous studies similarly find that e-scooter users prefer bike infrastructure when available and resort to sidewalks when it is not (National Academies of Sciences, Engineering, and Medicine, 2023a, b). Moreover, e-scooters sharing roads with higher-speed vehicles such as cars, buses, and trucks increase the risk of traffic crashes (Yang et al., 2020). Therefore, providing safe bike lanes is strongly recommended to support e-scooter usage (Bozzi and Aguilera, 2021; Liazos et al., 2022; Szemere et al., 2024).

Incorporating segregated spaces for bicycles and e-scooters often requires reallocating space from sidewalks or roads. Consistent with sustainable mobility principles, reallocating road space is preferable as it affects less efficient and more polluting transport modes. Even if bike lanes cannot be established in the short or medium term, circulation restrictions should be complemented by regular maintenance of existing cycling infrastructure and by prioritizing infrastructure strengthening in urban planning agendas.

Previous literature guides other policy recommendations to promote e-scooter usage by improving safety (National Academies of Sciences, Engineering, and Medicine, 2023a, b). Recommended measures include conventional vehicle speed regulations, requirements for incident and injury reporting, restrictions on sidewalk riding, and the delineation of service areas and time restrictions. Additional recommendations include rider training programs, communication campaigns focused on safe school routes and regular evaluations of safety programs.

Given the significant adverse reaction to limiting e-scooter parking, it is relevant to study the convenience of the location of designated parking sites, the separation between them, and the distance to significant travel generation and attraction centers. Differentiated incorporation of stations can be considered, restricting fixed spots in high-activity areas and not establishing restrictions in low-density neighborhoods (Sobrino et al., 2023). Essentially, it is necessary to develop configurations that do not affect the aesthetics of public space, protect vulnerable users whose dedicated infrastructure is often invaded, and, at the same time, do not represent an insurmountable obstacle for e-scooter users.

Incorporating monetary penalties for infractions can help promote compliance with regulations and discourage risky behaviors by electric scooter users. Szemere et al. (2024) suggested that imposing significant penalties for traffic infractions, especially during the initial phase, is crucial. Additionally, the results indicate that while a fine negatively impacts the intention to use, its effect in terms of demand is low. Furthermore, evaluating aspects related to the cost of shared scooter services is also pertinent. As observed in the study, most users belong to the middle and lower strata, and the cost is an attribute with a significant adverse effect on the intention to use. Considering the potential of e-scooters as a complement to public transportation, it is pertinent to evaluate fare integration schemes so that the cost of lending e-scooters for the first and last mile of the journey is lower or included within the public transport fare.

While this study provides valuable insights into e-scooter usage patterns, there are some limitations to consider. First, our sample predominantly comprises younger respondents, with 72 % under the age of 30. Although this age concentration aligns with the demographic profile often associated with e-scooter users, it may limit the generalizability of our findings to a broader population, particularly older adults with different preferences or attitudes toward technology. Second, the latent construct of road unsafety was adapted to the specific context of the study, based on items validated in the literature and refined through a pilot survey. Although this approach provides relevant insights into how safety perceptions interact with regulatory policies, the measurement was context-specific. It may not capture the full range of safety perceptions in other settings. Therefore, the results should be interpreted cautiously, acknowledging that they may primarily reflect the perspectives and behaviors of younger adults in urban areas.

7. Conclusions

E-scooters have proven to be a practical and widely used substitute for cars and biking in the case of short trips and a complement to public transportation for long trips. Nevertheless, the operation of these devices has raised issues regarding road safety and the misuse of public spaces, requiring the implementation of regulatory policies. These regulations must be carefully designed, considering the diversity of individuals' characteristics, perceptions, and behaviors of users and non-users.

This study revealed a positive response to road safety policies regulating e-scooter users' behavior. Measures such as mandatory helmet use and the restriction of circulation to bike lanes and roads were well received. Our results indicate that individuals aware of the risks of riding these devices are more likely to accept restrictions and maintain a favorable intention to use them. However, an adverse reaction was observed to regulations limiting the freedom to leave scooters anywhere or imposing additional costs or fines in case of users' misbehavior.

The perception of *road unsafety* is the most influential factor in the intention to use, showing a generally negative effect that regulatory policies could counter. Future policies should focus on measures that safeguard road safety, leveraging the favorable attitude towards it. Authorities should collaborate with shared e-scooter companies to ensure adherence to these regulations and explore future programs to improve operation and the well-being of road users.

Regarding limitations, although our sampling aligns with the typical demographic profile of e-scooter users, we acknowledge that young, mid-income students may be overrepresented in our study. Similarly, the high proportion of non-user respondents in the sample could also influence the results. Future studies should, therefore, aim for a more accurately representative sample. Likewise, it is recommended to include the probability of being caught breaking traffic rules for e-scooters since the economic theory suggests that, when performing misconduct, individuals make rational decisions based on the expectation of being caught and fined. Furthermore, although the cost of using e-scooters was presented as a flat price to simplify the survey, this approach does not correspond to the typical two-part tariff scheme for shared e-scooter services. Therefore, it would be appropriate to present the cost difference between the base rate and the value per minute in future research.

Finally, differentiating between owners and non-owners of e-scooters, as well as between casual and frequent users, is also an interesting avenue for future research since, over time, the adaptation of road actors to the presence of electric scooters may justify the exploration of other policies.

CRediT authorship contribution statement

Ely Izquierdo: Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mauricio Orozco-Fontalvo:** Validation, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Margareth Gutiérrez:** Writing – review & editing, Validation, Supervision, Methodology, Data curation, Conceptualization. **Raul Ramos:** Writing – review & editing, Validation, Software, Methodology, Data curation, Conceptualization. **Victor Cantillo:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, 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.

Appendix

Measurement model

LatentVariable	Variable	Parameter(t − test)
Measurement indicators		
RoadUnsafety	α RU1	1.784 (10.34)
	α RU2	2.749 (7.71)
	α RU3	1.429 (10.98)
Thresholds		
RoadUnsafety	τ RU1_1	−4.321 (−11.90)
	τ RU1_2	−2.692 (−9.29)
	τ RU1_3	0.024 (0.10)
	τ RU1_4	2.107 (7.70)
	τ RU2_1	−5.007 (−8.36)
	τ RU2_2	−2.053 (−4.98)
	τ RU2_3	0.764 (2.03)
	τ RU2_4	3.645 (7.26)
	τ RU3_1	−2.402 (−10.13)
	τ RU3_2	−0.698 (−3.38)
	τ RU3_3	1.203 (5.78)
	τ RU3_4	2.736 (11.33)

Data availability

Data will be made available on request.

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