Transport Policy 163 (2025) 358–369

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Modeling the influence of built environment on pedestrian perceptions in colombian cities

María F. Paba-Larios [a], Margareth Gutiérrez [b,*], Raúl Ramos [c], Víctor Cantillo [a]

[a] Department of Civil Engineering, Universidad del Norte, Colombia
[b] Facultad de Ingeniería, Arquitectura y Diseño, Universidad San Sebastián, Sede Santiago, Chile
[c] Departamento de Ingeniería de Transporte y Logística, Pontificia Universidad Católica de Chile, Santiago, Chile

ARTICLE INFO

Keywords:
Walkability
Pedestrians
Built environment
Perceptions
Safety
Comfort

ABSTRACT

Walking is a cornerstone of urban mobility in Latin America. Therefore, policies that improve pedestrians' perception of the built environment are crucial for policymakers and researchers alike. This paper investigates the influence of built environment factors on perceptions of *safety and comfort,* as well as pedestrians' preferences for sidewalk characteristics in two Colombian cities: Barranquilla and Santa Marta. For this purpose, we designed a novel survey that combines a choice experiment using real images of residential and commercial areas with a set of perception indicators to estimate hybrid choice models. The study's findings have significant practical implications for urban planning and policy development. In the commercial sector, sidewalk width is the most relevant attribute, followed by obstacles and, to a lesser extent, the presence of pedestrians. In residential sectors, the attractiveness of the environment, the presence of pedestrians, the condition of the sidewalk, and the existence of obstacles are highly relevant in explaining pedestrian demand behavior. The hybrid model indicates that sidewalk width and the presence of obstacles impact the perception of *comfort* and *safety* in both sectors. On the other hand, the presence of pedestrians has a positive effect on *safety* but a negative effect on *comfort*. These results show that physical attributes of the built environment influence pedestrian perceptions. Improvements in pedestrian infrastructure and the building environment are necessary to encourage walking as an active mode of transportation. They include promoting mixed land use, widening sidewalks, removing obstacles, and maintaining them to ensure continuity and good condition.

1. Introduction

In the last decades, Latin America has experienced accelerated growth in its urban population. In the 1950s, about 40% of the population lived in urban areas; however, nowadays, over 80% of the population lives in cities (United Nations, 2018). This rapid growth of the urban population has put pressure on the transport systems of the region, which, in most cases, rely on poor pedestrian infrastructure and semi-formal public transport services (Moscoso et al., 2019). However, despite these challenges, walking has remained a cornerstone of urban mobility in Latin America due to the region's high urban densities and low motorization rates (Serebrisky et al., 2019). Over half of the urban trips involve a walking stage, either as the main transport mode or to access public transportation (Table 1). This underscores the potential for improvement in pedestrian infrastructure and the need to understand pedestrians' behavior and how they perceive the urban built environment to enhance policy decisions.

Several authors have studied which attributes of the built environment have a greater impact on pedestrians' perceptions in Latin America. Table 2 presents a synthesis of these studies (denoted with letters a to k) and a selection of literature reviews and international papers as benchmarks (denoted with letters q to z).[1] We have organized the results into four primary perception dimensions: *quality, comfort, safety,* and *security*. Table 2 shows that the physical attributes of the built environment are crucial for pedestrian perceptions. For instance, the sidewalk's width and condition and the presence of obstacles are critical in all dimensions of the pedestrians' perceptions. Other urban attributes of public spaces, such as the presence of trees and green areas, influence

* Corresponding author.
E-mail address: margareth.gutierrez@uss.cl (M. Gutiérrez).

[1] We focus on papers that study how the built environment impacts pedestrian perceptions in Latin America. For exhaustive literature reviews on pedestrian perception, walkability, and other related topics, see, e.g., Ferreira et al. (2022), Nag et al. (2020) and Arellana et al. (2020a).

https://doi.org/10.1016/j.tranpol.2025.01.024
Received 12 July 2024; Received in revised form 31 October 2024; Accepted 15 January 2025
Available online 17 January 2025

Table 1
Modal split of transport in various cities (OMU, 2023).

	Bogotá	Buenos Aires	Mexico City	Panama	Rio de Janeiro	Salvador de Bahia	Sao Paulo	Santiago
Public	34.2	37.8	45.5	38.1	47.3	34.9	30.9	19.8
Metro/train	0.0	11.2	11.9	1.0	6.2	0.0	11.1	5.9
Bus/BRT	34.2	26.6	33.6	37.1	41.1	34.9	19.8	13.9
Active	32.1	28.5	30.3	8.3	28.3	36.2	32.7	41.2
Walk	24.7	24.6	27.0	8.1	27.2	35.3	31.8	36.9
Bicycle	7.4	3.9	1.8	0.2	1.1	0.9	0.9	4.3
Individual	24.5	31.5	23.1	45.4	23.4	22.4	30.6	33.0
Car	14.3	26.8	16.9	35.2	22.7	19.1	27.0	27.5
Taxi	4.5	1.6	5.3	9.3	0.2	1.4	3.0	4.9
Motorcycle	5.7	3.1	0.9	0.9	0.5	1.9	0.6	0.6
Others	9.1	2.3	1.1	8.3	1.0	6.3	5.8	6.0
Year	2019	2018	2017	2014	2011	2012	2017	2012

comfort, while lighting is crucial for *security*. Building characteristics and land uses also play a significant role. For example, the number of shops and the aesthetic of the building strongly affect pedestrians' perceptions of *quality, comfort*, and *security*.

Beyond physical attributes, other characteristics of the built environment impact pedestrian perception. For example, people's presence positively impacts *security*; however, crowding harms *comfort*. Not surprisingly, police officers and surveillance cameras improve *security*, while crime records reduce it. Pedestrian perception is also affected by the transport system. *Safety* is affected by traffic control devices, pedestrian facilities, and traffic speeds, while car congestion and traffic flow negatively impact *safety* and *comfort.*

Although previous research in Latin America has improved our understanding of how the built environment influences pedestrians' perceptions, three gaps remain in the literature. First, previous studies conducted in Latin America have identified that the presence of shops and the predominant land use significantly impacts the perception of the built environment (Arellana et al., 2020a; Guzman et al., 2022; Herrmann-Lunecke et al., 2021; Iglesias et al., 2013; Ruiz-Padillo et al., 2018, 2022; Torres et al., 2024). However, prior studies often fail to consider that other built environment attributes may be valued differently depending on the area's predominant land use. For instance, attributes such as the presence of trees or crowded sidewalks might affect perceptions of *safety* and *comfort* differently in commercial versus residential areas (Basu et al., 2022; Cho et al., 2009; Ferreira et al., 2022). This consideration is especially relevant in the region, as many cities lack a balanced land use mix, resulting in distinct commercial areas, often centered in city hubs, separated from residential zones.

Second, most studies in Latin America gather individuals' perceptions based on environments they recently or frequently experienced (e.g., Guzman et al., 2022; Vallejo-Borda et al., 2020). This can result in biased estimations due to limited variability in the studied attributes. It also may lead to endogeneity issues caused by omitted variables, as it is challenging to account for all the elements respondents consider when assessing the built environment (Guerrero et al., 2022, 2024).

Third, many studies rely solely on perception indicators without including individual preferences. These studies typically use the Structural Equation Modeling (SEM) framework, which may not be sufficient when a broader, quantifiable understanding of preferences is needed to evaluate current or hypothetical scenarios.

This paper aims to fill these gaps in three ways. Firstly, unlike previous works, we consider two distinctive land uses: residential and commercial. This novel approach allows us to identify and compare which urban environment characteristics affect pedestrian perceptions in each context, contrast our results with previous models, and formulate specific policy recommendations for each context.

The second contribution of our study concerns the survey design. We use a Stated Preference (SP) choice experiment where the respondents choose the most attractive alternative among three real images meticulously selected to ensure the validity of our experimental design. In addition to the choice experiment, our survey asks for a set of indicators related to respondents' perceptions regarding the built environment of each alternative, which allows us to obtain respondents' perceptions in a wide variety of factual scenarios, improving the validity of our results. Finally, our survey also includes a socioeconomic questionnaire to understand how socioeconomic factors may influence pedestrian perceptions and behavior.

We apply this novel survey to evaluate how the built environment influences pedestrians' perceptions and behavior in two Colombian cities, Barranquilla and Santa Marta, two nearby port cities with similar weather, culture, and customs. These cities were chosen due to their similar characteristics, making them ideal for this study. Our sample consists of 546 complete surveys by individuals over 18 years old who considered walking a mode of transportation and had internet access to complete the survey. 261 surveys were captured for the commercial environment, while 285 surveys were obtained for the residential environment.

The third contribution of this paper concerns our modeling strategy, as we need to integrate the data from the perception indicators and the SP choice experiment. To achieve this, we rely on a Hybrid Choice Modeling (HCM) approach, where a Multiple Indicator Multiple Cause (MIMIC) model is used to construct two latent variables –namely *safety* and *comfort*– that simultaneously explain the perception indicators and the respondent's choices (Ben-Akiva et al., 2002; Raveau et al., 2012; Walker, 2001). This modeling approach is grounded on the Random Utility Theory; therefore, it can be used to represent individual preferences, estimate aggregate demand functions, and compute welfare gains due to changes in the explanatory variables. Although common in the transport literature, the HCM has yet to be used widely to assess which built environment characteristics affect pedestrian perceptions and behavior.

The rest of the paper is organized as follows. Section 2 explains the three stages of our survey design in detail. Section 3 introduces the case study, providing context on the cities where the survey was implemented and describing the data collection process. Section 4 presents the main findings of the HCM model for each context under study. It also presents an elasticity analysis to better understand the differences between commercial and residential contexts. Section 5 offers policy recommendations derived from the model results, and Section 6 concludes the paper, summarizing the essential findings and outlining the study's limitations.

2. Survey design

Based on the extensive literature review conducted to identify the psychological, urban environment, and sociodemographic factors in the choice of sidewalks and walking areas, we designed a first draft of the questionnaire and the psychometric indicators that we would use to measure the latent variables. We tested this initial instrument through a virtual pilot survey to verify that it could accurately measure the

Table 2
Related literature: Urban environment variables affecting *quality, comfort, safety* and *security* perceptions in Latin America.

Variable	Quality[a]	Comfort	Safety	Security
Sidewalks				
Presence or existence	b	k	k,s,u,v,w,y	
Width	a,b,c,e,f,g,h,j	c	s,u	c,d,u
Condition/maintenance	a,c,g,h,j,r	c,u,v	i,s,u,v,x,y	c,u,z
Obstacles	a,b,e,f	c	u,v,x,y	
Slope	c,e,g,h	b,u,w		
Ramps	b,c,f,q,r		u,v	
Cleanliness	c,j,t	a,c,u,v,x	i	c,t,u,v
Vehicles parking	a,r	c		d
Continuity	a		s	
Block length	f	b		
Carriageway				
Condition		c	u	c
Width	f,j		s,u,v	c
Buildings				
Shops	c,h,j,t	g,u,v	i	c,u,v,z
Land use	a,b,e,j,t		s,t	t
Characteristics	c,	c	i,k	c,d,u
Aesthetic of buildings	e,h,r	a,b,g,u,v,w	i	c
High	c,	a,c,k,u,v	k	c
Graffiti		c		a
Fences		k	i,k	
Urban furniture/vegetation				
Lighting	c,j	u,v	u	b,c,u,v,w,z
Benches	j	u		
Trees	c,j,t	a,b,u,v,w,x	t	d,t,u,z
Green areas	a,b,c	c,k,u,v,w,x	k	
People				
Presence of other pedestrians		c,j,k,u,v	i,k,u	a,b,c,d,u,v,w,z
Bike flow		j		
Police	e,h		i,u	a,c,g,j
Street vendors		u		
Neighborhood				
Noise	c,j	c,u		c
Security cameras				a,b,j
Crime records				a,b,u,v
Police station				b
Transport system				
Public transport	a,b,c,f,j,r		s,u	c
Traffic control devices	j	k	a,b,u,v,k	
Pedestrian/crossing facilities		c	a,s,u,v,x	c
Congestion/traffic flow	j,r	b,c,k,u,v	a,b,k,u,v,x	c
Traffic speed	j		a,b,u,v,y	c
Car crash record/risk	e,h,r		b,g,u	j
Connectivity	e,h	g	s,u	
Bicycle facilities	r		u	

Studies conducted in Latin America: a) Arellana et al., 2020a, b) Guzman et al. (2022), c) Herrmann-Lunecke et al. (2021), d) Hurtubia et al. (2015), e) Larranaga et al. (2019), f) Rodriguez-Valencia et al. (2020), g) Ruiz-Padillo et al. (2018), h) Ruiz-Padillo et al. (2022), i) Iglesias et al. (2013), j) Vallejo-Borda et al. (2020), k) Rossetti et al. (2019).
Literature reviews and other selected studies: q) Campisi et al. (2022), r) Georgiou et al. (2021), s) Cho et al. (2009), t) Basu et al. (2022), u) Ferreira et al. (2022), v) Ferrer et al. (2015), w) Ferrer and Ruiz (2018), x) Le et al. (2021), y) Narayanan (2020), z) Park and Garcia (2020).
[a] Quality includes Perceived Quality, Pedestrian Level of Service (PLOS), Walkability or Attractiveness studies.

expected variables and was easily understandable for the target population. We obtained 84 responses for the commercial sector and 92 for the residential sector. Using these data, we estimated preliminary models, which allowed for adjustments to the attributes of the SP survey and corrections to the presentation and language to reduce potential confusion among respondents.

Due to COVID-19 restrictions, we opted for an online survey. While this method allowed us to reach a broad audience through email and social media, it may have limited participation from individuals with less internet access or digital literacy. However, efforts were made to ensure diverse representation, and the results were carefully analyzed to account for any potential biases.

The final survey design consists of three stages. In the first stage, we presented the two stated Preferences (SP) experiments: one for a residential context and the other for a commercial context. In the second stage, we include psychometric indicators to assess perceptions of environmental *safety* and *comfort*. In the final stage, we gather information to characterize the respondents, including their most frequently used mode of transportation and the socioeconomic characteristics of their household and themselves.

We conducted the survey between September and mid-October 2020 in Barranquilla and Santa Marta. The cultural, climatic, and other similarities between the two cities ensured the responses were relevant and comparable, allowing for a more cohesive data analysis. Fig. 1 presents a flow chart of our complete methodology.

2.1. Stated choice experiment

We designed two stated choice experiments, one for a residential context and another for a commercial context. In each experiment, individuals had to choose between 3 unlabeled alternatives, ranking their preferences from the most attractive to the least attractive alternative. Each experiment considered an orthogonal design consisting of 16 choice situations in four blocks, then each individual faced four choice situations.

We carefully selected the most relevant set of attributes for this type of study, which primarily included the width and condition of the sidewalk, as well as the presence of shade and pedestrians. Considering the unique context of Colombian cities, we also included the presence of fences adjacent to the sidewalk and the area's attractiveness. Table 3 presents the attributes considered in the design of the commercial sector survey, while Table 4 shows the attributes and characteristics of the residential sector survey. All the attributes considered have two levels of variation, specified as a dummy variable that takes the value of 1 if it has the described characteristic or 0 otherwise.

We first designed the SP survey, carefully combining the attributes to ensure no alternative was dominant in the choice experiment, as shown in Fig. 2. This approach not only enhances the authenticity of the study but also ensures it is comprehensive and representative. Based on this design, we then conducted an exhaustive search for images that met those characteristics using Google Street View (Google, 2020). We obtained images from six Colombian cities: Bogotá, Medellín, Barranquilla, Santa Marta, Bucaramanga, and Valledupar. We did not tell respondents which city the photo belonged to. This avoided sample bias and provided a variety of scenarios.

The pilot survey revealed that the time of day significantly impacts *safety* perception. However, the COVID-19 pandemic restrictions and the need to comply with our experimental design led us to use Google Street View images for our choice scenarios. Unfortunately, only daytime images are available on Google Street View, so we could not include the time of day as an environmental variable in our model.

2.2. Perception survey

The second stage of the survey was designed to explore the respondents' perceptions more deeply. It included psychometric indicators associated with perceptions of *safety* and *comfort* while walking

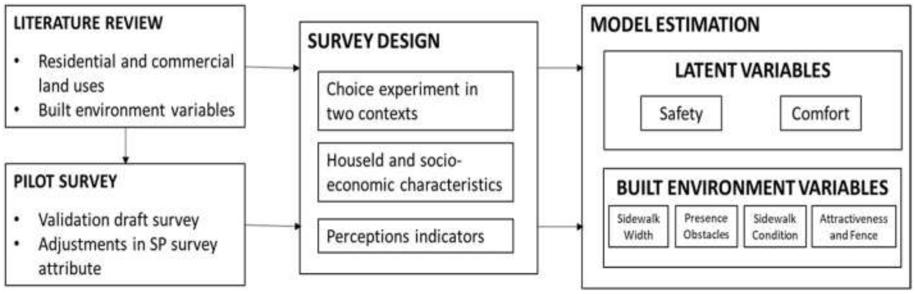

Fig. 1. Methodological flow chart.

Table 3
Attributes to evaluate - Commercial Sector.

Attribute	Abbreviation	Description of Levels
Pedestrian flow	Pedestrians	When the sidewalk is empty (0), if it has people (1)
Presence of obstacles	Obstacles	Without obstacles (0), with obstacles (1)
Sidewalk width	Width	Less than 1.2 m (fixed)
	Width 1	If the width is between 1.2 m and 1.8 m (1), otherwise (0)
	Width 2	If the width is greater than 1.8 m (1), otherwise (0)
Sidewalk condition	Condition	Bad (0), good(1)
Presence of shade from trees	Shade	Without shade (0), with shade (1)

Table 4
Attributes to evaluate - Residential Sector.

Attribute	Abbreviation	Description of Levels
Pedestrian flow	Pedestrians	When the sidewalk is empty (0), if it has people (1)
Presence of obstacles	Obstacles	Without obstacles (0), with obstacles (1)
Sidewalk width	Width	Less than 1.5 m (0), More than 1.5 m (1)
Sidewalk condition	Condition	Bad (0), good(1)
Presence of shade from trees	Shade	Without shade (0), with shade (1)
Presence of fences alongside sidewalks	Fence	Without fence (0), with fence (1)
Attractiveness of the area	Attractiveness	Less attractive (0), Very attractive (1)

in the areas shown in the images.[2] The responses to these indicators were collected using a 5-point Likert scale, where 1 represented complete disagreement, and 5 represented complete agreement with the statement in the question. This scale provided a detailed understanding of the respondents' viewpoints, further analyzed through confirmatory factor analysis to yield the latent variables shown in Table 5. Notice that respondents were asked to evaluate three *safety* indicators and three *comfort* indicators for each of the three alternatives in the four-choice scenarios. Thus, each individual responded to 72 indicators in addition to the four-choice scenarios.

2.3. Socio-economic questionnaire

The final part of the survey is dedicated to understanding the socioeconomic characteristics of the respondents and their households. It includes age, gender, marital status, educational level, car ownership, and socioeconomic stratification. 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 signify high income. Consequently, it has been used in Colombia as a proxy variable for household income (e.g., Cantillo et al., 2015; Chica-Olmo et al., 2020; Gutiérrez et al., 2021; Ramos et al., 2017).

3. Case study

Barranquilla and Santa Marta are two capital cities in Colombia's northern region on the Caribbean coast (Fig. 3). Barranquilla is an important port and industrial center with a population of nearly 1.3 million in 2018, nearly three times the size of Santa Marta, with approximately 500,000 inhabitants (DANE, 2018). Despite their differences in size, both cities have similar cultural, climatic, and socioeconomic characteristics, making them effectively comparable. Both cities have warm and humid weather all year and a significant tourism industry due to their proximity to the Caribbean Sea.

According to the latest population census (DANE, 2018), the distribution of household stratification in capital cities shows that more than 63% of households belong to strata 1 and 2 (low-income). Meanwhile, the smallest proportion (4.29%) belongs to the strata, 5 and 6 (high income). Table 6 presents the main socioeconomic characteristics of the two cities according to the population census and the modal share.

In Barranquilla, public transport accounts for around 36.7% of all trips made on a typical workday, followed by 28.9% of trips made by foot, making it the city's second most popular mode of transportation (TPD Ingeniería., 2018). Close behind comes private transportation, which accounts for 20.7% and primarily comprises cars and motorcycles. Other modes, by contrast, account for a significantly lesser fraction. On the other hand, in Santa Marta, 27% of trips on a typical day are made using non-motorized transportation (walking or bicycling), while 39% are completed via public transit (Financiera del Desarrollo Territorial., 2016).

3.1. Data collection

The data collection stage finished with 546 complete surveys by individuals over 18 years old who considered walking a mode of transportation and had internet access to complete the survey. Approximately 65% of the surveys were conducted in Barranquilla. A total of 261 surveys were captured for the commercial environment, averaging 65 surveys per block, while 285 surveys were obtained for a residential environment, averaging 71 surveys per block.

The necessary sample size for SP experiments is an ongoing debate in the discrete choice modeling literature (de Bekker-Grob et al., 2015; Sriwastava and Reichert, 2023; Yang et al., 2015). There is no universally accepted approach or formula to compute the sample size for SP experiments. Finding research with relatively small samples (between 70 and 120 surveys) is possible. Some studies suggest that 75–100 interviews per population segment may be appropriate (Swanson et al., 1992). In turn, Bliemer and Rose (2009) propose an approach to estimate the minimum sample size, which depends on having available

[2] In Spanish, the word *seguridad* means both safety and security. Therefore, our latent variable *safety* is closely related to both concepts.

Fig. 2. Survey alternative examples (©Google, 2020).

Table 5
Indicators for perceptions and attitudes and latent variables associated with.

Statements	Latent Variable
I feel safe walking here.	*Safety*
This space allows me to walk with friends.	
I feel protected from vehicles.	
This area is comfortable for walking.	*Comfort*
An elderly person or someone with a disability can walk through this area without issues.	
Walking on this sidewalk seems stressful to me.	

parameter values. We follow the "rule of thumbs" recommendations by Ortúzar and Willumsen (2024) and Louviere (2000). Nevertheless, we compute the minimum sample size following Orme (1998) to establish a minimum reference value. Using this approach, we obtain a minimum sample size of 125 individuals, a number that is below our actual number of surveys (see Appendix A).

Table 6 presents the main descriptive statistics of the sample. Compared to the data from the latest census (DANE, 2018), the sample presents similar characteristics to those of the population in the two cities studied. The gender distribution is quite similar, with a slightly higher percentage of women than men. The distribution of households by socioeconomic stratum is also similar, with the higher strata (5 and 6) representing the smallest percentage in both the population and our sample.

The surveys were almost equally distributed between men and women, with women representing 50% in the commercial sector and 52% in the residential sector. Regarding the age of the respondents, the most represented group in the commercial sector was between 27 and 36 years old, while in the residential sector, it was between 18 and 26 years old. In both sectors, the age ranges with the lowest proportion of respondents were those under 18 and those over 56.

Fig. 3. Location of the two studied cities.

People were asked what their primary mode of transportation was or the one they used most frequently for non-routine trips such as errands or visits to identify which respondents favored walking over other modes. It was found that, of those surveyed with images of the commercial sector, only 10% frequently walked, and 8% used bicycles,

Table 6
Comparison of survey sample characteristics with 2018 census data for Barranquilla and Santa Marta.

Category	Sample		Census data	
	Commercial Sector	Residential Sector	Barranquilla	Santa Marta[a]
Gender				
Male	49%	48%	48%	48%
Female	50%	52%	52%	52%
Prefer not to answer	1%	–	–	–
Age				
18–24 years	30%	38%	17%	19%
25–34 years	23%	27%	22%	23%
35–44 years	22%	16%	19%	20%
45–54 years	15%	14%	16%	16%
Over 55 years	10%	5%	26%	22%
Socio-Economic Stratum				
1	4%	24%	42%	41%
2	37%	20%	23%	20%
3	42%	34%	20%	28%
4	15%	18%	9%	5%
5	2%	2%	3%	1%
6	1%	2%	2%	2%
Does not have/not know	–	–	1%	3%
Education Level				
High School	46%	40%	–	–
Postgraduate	10%	10%	–	–
University Degree	22%	26%	–	–
Technical/ Technologist	22%	23%	–	–
Owns a Car?				
Yes	31%	28%	–	–
No	69%	72%	–	–
Owns a Motorcycle?				
Yes	25%	18%	–	–
No	75%	82%	–	–
Owns a Bicycle?				
Yes	38%	38%	–	–
No	62%	62%	–	–
Modes of Transport				
Walking	10%	5%	29%	22%
Bicycle	8%	10%	2%	5%
Motorized Modes	82%	85%		
Private Transportation (Car and Motorcycle)	53%	49%	21%	17%
Public Transport	28%	36%	36%	39%
Others	1%	0%	12%	17%

[a] Private Transportation does not include Motorcycles (Financiera del Desarrollo Territorial., 2016).

compared to motorized modes, which were the most used by 82% of the sample (32% cars, 28% public transportation, 21% motorcycles, and 1% others). Likewise, motorized modes were prioritized by the residential sector sample, accounting for up to 85% (36% public transportation, 28% and 21% motorcycles). In comparison, active modes only represented 15% of the sample, with walking being the least used mode for regular trips. However, since public transportation users in Colombia must walk to access the service, almost 40% of the respondents frequently walk during one stage of their trip.

Of the total respondents, the majority belonged to socioeconomic stratum 3, followed by strata 1 and 2, indicating a middle to low-income level. 46% of the individuals in the residential sector sample had completed high school, and 40% in the commercial sector, followed by those who had attained a university degree with 22% and 26%, respectively, and those who had completed technical and technological studies with 22% in the residential sector and 23% in the commercial sector, while only 10% had completed postgraduate studies in both contexts. Of the total sample, less than 40% of respondents had a car at home, and less than 25% owned a motorcycle.

4. Model estimation results

A meticulous decision-making process characterized our modeling approach. We began the estimation with a multinomial logit (MNL) model, defining the initial parameters for each attribute: sidewalk width, the presence of obstacles, pedestrian density, and the condition of the sidewalk. We also evaluated the presence of fences and shades in the residential sector; since the last attribute was not significantly different from zero, we excluded it from the analysis for both residential and commercial environments.

We implemented the ranking explosion and evaluated the models, only to find that the fit obtained was inferior to those without explosion. This thorough evaluation led us to prefer the latter. We then introduced an error component through the well-known *pseudo-panel* effect to identify the correlation between each individual's different responses (Ortúzar and Willumsen, 2024). However, these components were not significantly different from zero, compelling their exclusion from the final specification.

Expanding on the base model, we estimate two Hybrid Choice Models (HCM), including latent variables *safety* and *comfort.* The HCM has two components. The first component is an SEM-MIMIC model, which is typically employed to uncover latent variables, such as individual attitudes and perceptions, by identifying relationships or correlations between observed attributes and unobserved attitudes or perceptions (Bollen, 1989). Latent variables are explained by the socioeconomic characteristics of the individuals and the physical attributes of each alternative. Simultaneously, the latent variables explain six perception indicators through the measurement equations, three for each variable, following the minimum recommended by the literature.

The second component of the HCM is a Discrete Choice Model (DCM) that represents individual preferences by modeling decisions in real or hypothetical scenarios. HCM incorporates latent variables into the individual's utility function, providing insight into how attitudes and perceptions, which cannot be directly observed, may influence the decision-making process and enabling the representation of preferences by computing choice probabilities for each alternative. Thus, the capabilities of modeling latent variables of the SEM-MIMIC approach are combined with the possibility of modeling individual choices of the DCM. Moreover, unlike the SEM-MIMIC approach, the HCM allows for computing the relative marginal valuation of latent variables and qualitative attributes, which is helpful for the economic evaluation of projects.

The structure of the HCM models for the commercial and residential sectors are detailed in Fig. 4a and b, respectively. Indicators 1, 2, and 3 are related to the *safety* variable, while indicators 4, 5, and 6 are related to the *comfort* variable. Additionally, the width, condition, pedestrian density, and obstacles on the sidewalk could be related to both variables in the commercial sector. In the residential sector, attractiveness and the presence of fences in adjacent houses were also considered. It is important to note that the indicators are specific to each alternative.

The utility of each alternative is a linear function of the two latent variables. Note, however, that the utility function depends indirectly on the attributes of the built environment depicted in the images and the individual's characteristics since the latent constructs are functions of the environmental attributes and the respondents' socioeconomic characteristics.

Table 7 presents the estimates obtained from the hybrid models for the commercial and residential sectors. Focusing on the latent variable *safety* in the commercial context, it can be inferred that sidewalk width is significant, and its positive sign indicates that the wider the sidewalk, the greater the sense of *safety* (Ferreira et al., 2022). The opposite occurs with obstacles, where the negative sign indicates that people perceive a sidewalk with obstacles as unsafe (Ferrer et al., 2015; Le et al., 2021; Narayanan, 2020). The presence of pedestrians on sidewalks positively affects the perception of *safety*. This may be because having more people in the same space makes pedestrians feel accompanied.

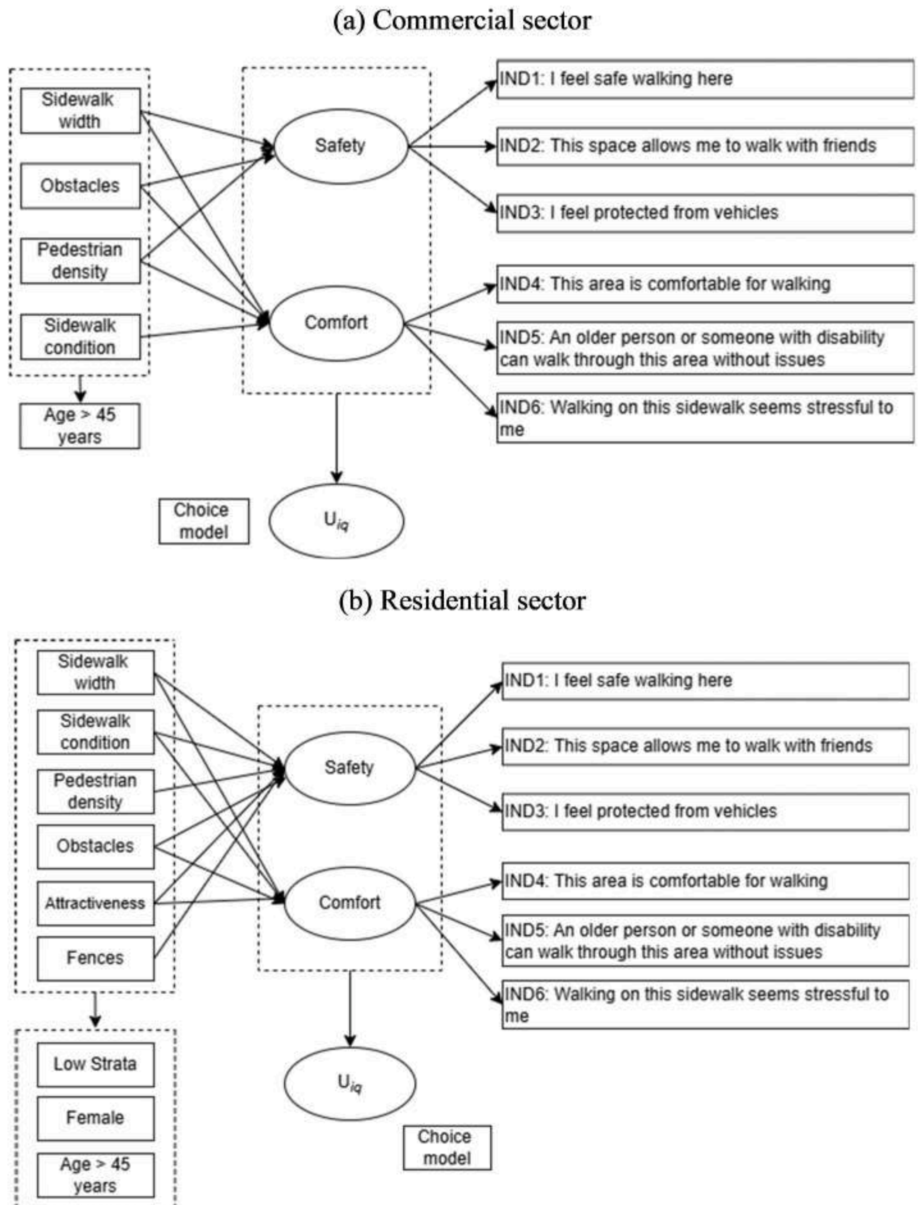

Fig. 4. Hybrid choice model structure.

In the residential sector, the perception of *safety* follows a similar pattern, with sidewalk width, presence of obstacles, and pedestrian density playing key roles, as seen in the commercial sector. The difference between the two contexts can be better understood by examining how individuals' socioeconomic backgrounds interact with the built environment attributes. For instance, sidewalk width is more significant for individuals from lower socioeconomic strata than those from middle and upper strata. This may be because sidewalks in lower-income areas tend to be narrower or may not exist at all.

When it comes to obstacles, individuals over the age of 44 feel less safe encountering them than younger people. This could be attributed to the decline in agility and ability to navigate obstacles often associated with aging or the fear of falling (Gebremariam et al., 2024; Doulabi et al., 2021). Aesthetically attractive areas are generally perceived as safer. However, contrary to our expectations, women do not feel safer in attractive environments compared to men. The presence of pedestrians plays a crucial role in improving perceptions of *safety*, likely due to the increased sense of social control (Arellana et al., 2020a; Guzman et al., 2022; Hurtubia et al., 2015). The condition of the pedestrian walkway was also found to be highly significant in shaping *safety* perceptions.

On the other hand, when homes are fenced, the sense of *safety* decreases. According to our model, women feel less safe in the presence of fences compared to men, possibly due to the feelings of isolation and reduced social control that fences can induce (Herrmann-Lunecke et al., 2021; Iglesias et al., 2013).

In the analysis of the latent variable *comfort*, sidewalk width emerges as a highly influential attribute in both commercial and residential sectors, highlighting that wider sidewalks contribute significantly to a greater sense of pedestrian *comfort* (Herrmann-Lunecke et al., 2021). This is consistent across both settings, but the impact of other variables reveals notable differences between the two environments.

In the commercial sector, obstacles such as informal vendor stalls and other objects that invade public spaces substantially increase discomfort, especially for individuals over 44 years old. This suggests that older pedestrians experience more difficulty navigating commercial areas when faced with obstacles, likely due to reduced mobility (Herrmann-Lunecke et al., 2021). Additionally, the presence of pedestrians harms *comfort* perceptions, possibly due to crowding, which

Table 7
HCM model results.

	Model Component	Attribute	HCM Commercial Estimate	(*t*-test)	HCM Residential Estimate	(*t*-test)
Safety	Structural Equation	Width 1	0.683	(11.11)	0.299	(5.53)
		Low stratum	–	–	0.213	(4.45)
		Width 2	1.491	(25.10)	–	–
		Pedestrians	0.098	(1.95)	0.238	(5.52)
		Obstacles	−0.389	(-8.65)	−0.103	(-2.00)
		Age > 45 years	–	–	−0.319	(-3.67)
		Condition	–	–	0.250	(5.27)
		Fence	–	–	−0.002	(-0.03)
		Female	–	–	−0.262	(-4.25)
		Attractiveness	–	–	0.567	(7.54)
		Female	–	–	−0.152	(-1.67)
	Measurement Equation	IND1	2.452	(18.37)	2.847	(16.11)
		IND2	2.442	(18.18)	2.109	(19.16)
		IND3	1.476	(21.62)	1.566	(20.24)
Comfort	Structural Equation	Width 1	0.470	(7.55)	0.660	(14.40)
		Width 2	1.306	(22.39)	–	–
		Pedestrians	−0.169	(-3.51)	–	–
		Obstacles	−0.497	(-10.00)	−0.563	(-12.61)
		Age > 45 years	−0.195	(-2.68)	–	–
		Condition	0.175	(3.75)	0.485	(10.54)
		Age > 45 years	–	–	−0.251	(-3.04)
		Attractiveness	–	–	0.526	(7.86)
		Female	–	–	−0.348	(-4.25)
	Measurement Equation	IND4	3.179	(15.96)	3.535	(14.56)
		IND5	2.930	(16.90)	2.326	(19.83)
		IND6	1.475	(20.61)	1.312	(20.45)
	Choice model	*Safety*	0.714	(8.23)	0.733	(7.69)
		Comfort	0.226	(3.05)	0.778	(9.21)
Number of observations			976		1096	
Log-likelihood			−955.08		−1085.43	

contrasts with the positive impact of pedestrian presence on *safety* (Ferreira et al., 2022). On the other hand, the condition of the sidewalk plays a key role in *comfort*, with well-maintained surfaces making walking more pleasant for all pedestrians, regardless of age.

In the residential sector, *comfort* is influenced by a different set of preferences. While sidewalk width remains significant, obstacles become the most penalizing factor for all pedestrians. Interestingly, sidewalk condition is the second most influential factor in this setting, contributing positively to the perception of *comfort* (Herrmann-Lunecke et al., 2021). However, for older adults, improvements in sidewalk conditions do not significantly enhance *comfort*, which may suggest that their discomfort stems from factors beyond physical infrastructure, such as reduced mobility or increased sensitivity to obstacles (Arellana et al., 2020a; Guzman et al., 2022). Moreover, the area's attractiveness notably shapes *comfort* perceptions, particularly in residential environments. However, women do not feel more comfortable in aesthetically pleasing environments than men. A similar result was found by Basu et al. (2022), who concluded that women tend to have a lower perception of attractiveness.

Regarding perception indicators, the latent variable *safety* greatly contributes to people feeling safe on a sidewalk. Additionally, the perception that a sidewalk with certain physical characteristics allows walking in the company of others and protects pedestrians from vehicles on the roads is also explained by a high sense of *safety*. The sensation of *comfort* positively influences the perception that the space allows for pleasant and comfortable walks and that pedestrians with mobility restrictions (elderly and/or people with motor disabilities) can transit without difficulties. Furthermore, the greater the individual's sense of *comfort*, the less stressful they perceive walking on the sidewalk. The models indicate that the estimated parameters related to the *safety* and *comfort* latent variable are positive and significant in both sectors.

The estimated parameters for the explanatory variables do not directly indicate the magnitude of their effect on individuals' preferences. However, we can assess which variables most affect preferences by analyzing how a change in one attribute of an alternative impacts the probability of choosing that option. Since dummy variables describe environmental attributes, we first estimate the probability that individual q would choose alternative j when attribute X_j is set to 0 and then again when it is set to 1, keeping other attributes constant (Fountas and Anastasopoulos, 2017; Washington et al., 2020). We then calculate the semi-elasticity as the percentage change in probability when attribute X_j shifts from 0 to 1 and aggregate the results using sample enumeration.

For example, the first value in Table 8 indicates that the probability of choosing an alternative, increases by 34.5% when the variable "Width 1″ equals 1 (i.e., when the sidewalk width ranges from 1.2 m to 1.8 m) compared to when it is 0 (i.e., when the width is below 1.2 m).

As expected, the attribute that most impacts choice probability is sidewalk width, as it positively affects both *safety* and *comfort*. However, sidewalk width has differing effects in commercial and residential sectors. In the commercial sector, the sidewalk's width has an increasing marginal value. For instance, increasing the width from 1.0 m to 1.2 m raises choice probability by 35%, while an increase from 1.0 m to 1.8 m raises it by 114%. In contrast, in the residential sector, an increase in sidewalk width from 1.0 m to 1.2 m has the same effect as an increase to 1.8 m, raising choice probability by 50%. This indicates that increasing sidewalk width above 1.2 m does not yield additional gains in the residential sector. However, it is important to note that this result is based

Table 8
Semi-elasticities estimates.

Attribute	Commercial Sector	Residential Sector
Width 1 (1.2 m–1.8 m)	35%	50%
Width 2 (>1.8 m)	114%	–
Pedestrians	2%	8%
Obstacles	−19%	−23%
Condition	20%	29%
Fence	–	−5%
Attractiveness	–	33%

on images shown to respondents, generally with widths below 1.8 m, which aligns with the reality in Colombia, where residential sidewalks are rarely wider than this. Consequently, our model cannot estimate the valuation of sidewalk widths above this threshold. In contrast, commercial sidewalks in Colombia often exceed 1.8 m, allowing us to conclude that pedestrians value wide sidewalks more in commercial areas.

The attractiveness of the built environment is the second most influential factor in the residential sector, primarily because it improves both *safety* and *comfort*. The third most influential attribute is the condition of the sidewalk. Improving sidewalk condition increases choice probability by 29% in the residential sector and 20% in the commercial sector. This factor has a stronger impact in residential areas because it affects both latent variables, whereas in commercial areas, it only influences *comfort*. Conversely, fences only reduce choice probability by 5%, primarily affecting women's perception of *safety*, while men's perceptions remain largely unaffected.

Interestingly, while the presence of other pedestrians affects *safety* and *comfort* perceptions in the commercial sector, it has a low effect on choice probability. This is because crowding increases *safety* but almost offsets this with reduced *comfort*, resulting in a low net positive effect on pedestrian valuation. In residential areas, having more pedestrians does not impact *comfort*; thus, only the improvement in *safety* perception influences individuals' valuation of crowding.

5. Policy recommendations

The results of our model provide valuable guidance for urban policy recommendations. First, sidewalks in Colombian cities are typically narrow, discontinuous, uneven, and cluttered with obstacles (see Fig. 2a). According to our findings, these poor conditions harm perceptions of *comfort* and *safety* in both commercial and residential areas, particularly for older, low-income pedestrians. Local authorities should initiate public space improvements to widen sidewalks to over 1.5 m in residential areas and over 2.0 m in commercial zones. In Colombia, the standard for sidewalks defines that they must be at least 1.2 m wide. However, smaller widths are frequently observed. Footways 1.2 m wide do not allow for the comfortable movement of pedestrians in wheelchairs or with prams. Extending the minimum width to 1.5 m in residential areas and 2.0 m in commercial areas increases perceptions of *safety* and *comfort*, encouraging walking.

These interventions must also ensure that sidewalks are continuous and even, improving not only *comfort* and *safety* perceptions but also accessibility for all pedestrians. Additionally, fixed obstacles such as utility poles are commonly found on sidewalks; therefore, these projects should include undergrounding public service networks. Measures to prevent sidewalk encroachment by vendors and vehicles should also be part of the planning.

Our results highlight the impact of built environment aesthetics on perceptions of *safety* and *comfort* in residential areas, particularly among men. Local authorities should consider redesigning public spaces to incorporate urban furniture, plants, and green areas strategically placed to enhance urban aesthetics without compromising walkability. Additionally, monetary incentives for low-income homeowners to amend their facades could be considered a tool to improve perceptions of the built environment.

Local authorities may also consider revising fence regulations. While residents often use fences to deter robbery and crime within buildings, recent studies suggest they have minimal impact on crime rates (Adzande and Gyuse, 2017; Marks and Overall, 2015; Calonge-Reillo, 2022). However, our study and others have found that fences negatively affect pedestrians' sense of *safety*, especially among women (Herrmann-Lunecke et al., 2021; Iglesias et al., 2013). Thus, restricting fences to households with specific security needs may be beneficial.

Adjustments to real estate regulations should also be made. For example, new developments should include sidewalk improvements in their surroundings, and all new urban projects should meet high walkability standards. Land-use diversity should also be promoted by incentivizing the establishment of local shops and other amenities within walking distance of residential areas. However, sidewalk improvements, including more generous widths, should complement these policies to prevent pedestrian crowding and discomfort.

It is essential to involve the real estate sector in improving sidewalk conditions. To a large extent, discontinuities and obstacles in pathways are the result of interventions by builders and owners. Incentives and regulations should be designed so that the real estate sector participates in programs to recover and extend sidewalks. Also, more control by planning authorities is required.

6. Conclusions

In this paper, we evaluated the influence of infrastructure attributes on pedestrian perceptions in commercial and residential environments using data from two Colombian cities: Barranquilla and Santa Marta. We employed a novel instrument that combines a choice experiment using authentic images with a set of perception indicators to capture pedestrian preferences. HCM models were estimated for each sector, incorporating two latent variables: *comfort* and *safety*.

Our results highlight key differences between residential and commercial sectors relevant to policy formulation. In the residential sector, fences and building aesthetics influence *safety* perceptions, especially among women, whereas these variables are not influential in the commercial sector. Sidewalk width is more relevant for *safety* among low-income individuals in residential areas, while it holds broader importance for all individuals in commercial areas. For *comfort*, older individuals are more affected by the presence of obstacles in the commercial sector, although they are less impacted by sidewalk conditions in residential areas.

It is relevant to note the limitations of this research. First, since the surveys used real images from Google Street View, respondents may have considered characteristics not captured by our survey when ranking their preferences. Our model relies on latent variables to mitigate bias or inconsistencies in parameter estimation due to these omitted variables. However, including additional control variables or exploring alternative methods to address this issue could be a valuable direction for future research. The use of immersive virtual reality (Arellana et al., 2020b) can be useful to mitigate the restrictions of static images.

Second, only two latent variables were included in our model. Other constructs, such as individuals' environmental attitudes, predisposition to walk, or enjoyment of public spaces, could also affect pedestrian perceptions and preferences. Expanding the model to include these variables, perhaps by combining the HCM model with latent-class models, could be a natural extension of this research.

Third, due to COVID-19 restrictions, we conducted online surveys, which may have limited participation from individuals with restricted internet access or lower digital literacy. This limitation may be particularly impactful in developing countries like Colombia, where internet access is limited. Although we took measures to minimize representation issues, comparing our findings with results from in-person surveys could be essential to validate our conclusions. Finally, integrating psychological theories, such as the theory of planned behavior or theories on risk perception and well-being, could also be explored in future studies.

CRediT authorship contribution statement

María F. Paba-Larios: Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Margareth Gutiérrez:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Raúl Ramos:** Writing – review & editing, Visualization, Validation, Data curation. **Víctor Cantillo:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of interest statement

The authors declare no conflict of interest.

Acknowledgments

Víctor Cantillo acknowledges the Colombian Ministry of Science, Technology, and Innovation for the support in the STIC-AMSUD 22-STIC-09 project. Contract No. 112721-102- 20. Raúl Ramos acknowledges financial support from ANID BECAS/DOCTORADO NACIONAL 21180398 and Erasmus+ programme of the European Union.

APPENDIX A. SAMPLE SIZE

The minimum sample size for this experiment was calculated by a commonly used rule of thumb in discrete choice experiments proposed by Orme (1998). Orme's formula states that the number of respondents N is given by:

$$N \geq 500 \frac{c}{t \bullet a}$$

where c represents the largest number of levels of any attribute, t is the number of choice sets each respondent faced, and a represents the number of alternatives. For our design, the largest level of the attribute is three (sidewalk width in the commercial sector, see Table 3). Four choice sets are presented, and three alternatives are faced for each respondent. Therefore, the minimum number of respondents is 125, a number that is below our actual number of surveys.

APPENDIX B. EXAMPLE OF THE SURVEY

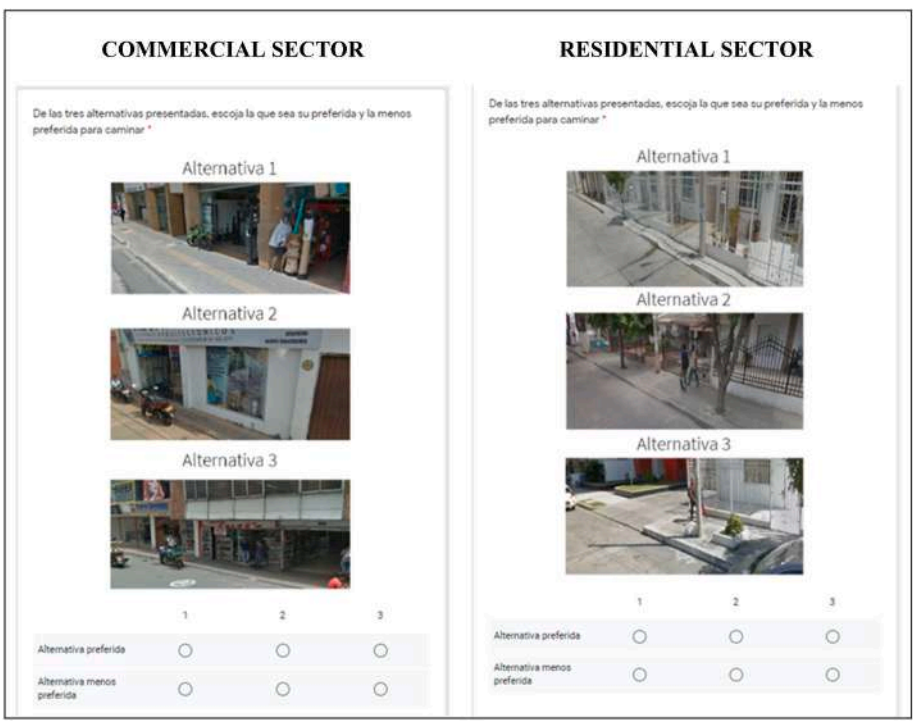

Fig. 5. Examples of a choice scenario for the commercial (left) and residential (right) sector.

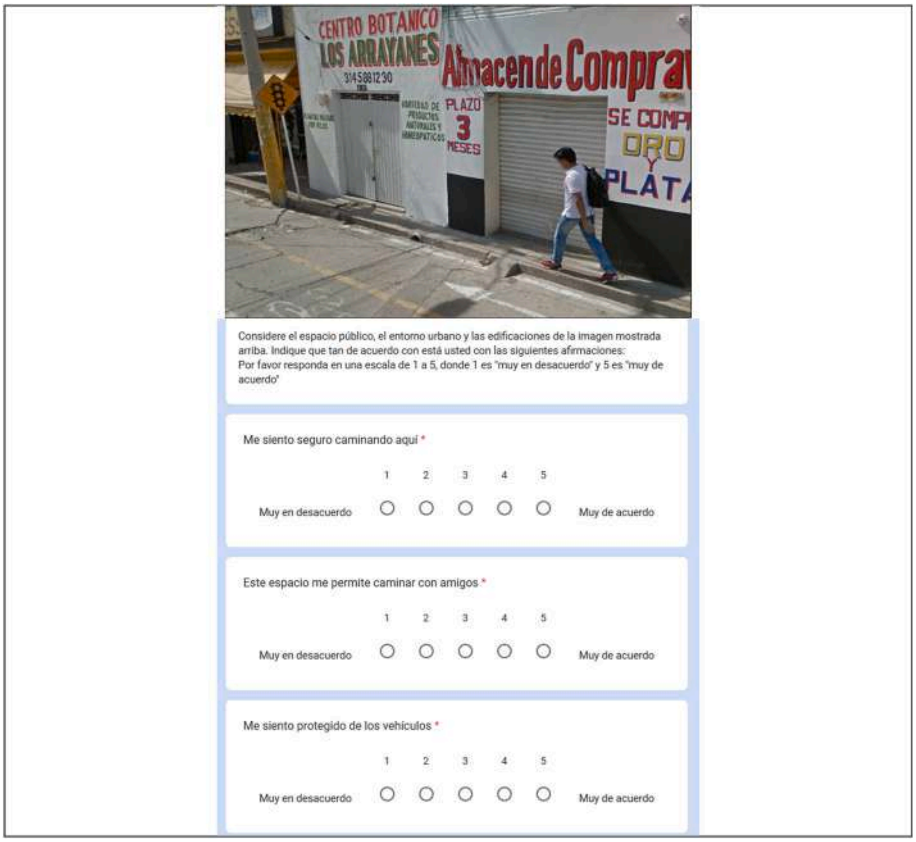

Fig. 6. Examples of the perception questionnaire for one alternative.

Data availability

Data will be made available on request.

References

Adzande, P., Gyuse, T.T., 2017. Territoriality and safety in urban residential neighborhoods in Nigeria. Journal of Urbanism: International Research on Placemaking and Urban Sustainability 10 (3), 333–355.

Arellana, J., Saltarín, M., Larrañaga, A.M., Alvarez, V., Henao, C.A., 2020a. Urban walkability considering pedestrians' perceptions of the built environment: a 10-year review and a case study in a medium-sized city in Latin America. Transport Rev. 40, 183–203.

Arellana, J., Garzón, L., Estrada, J., Cantillo, V., 2020b. On the use of virtual immersive reality for discrete choice experiments to modelling pedestrian behaviour. Journal of choice modelling 37, 100251.

Basu, N., Oviedo-Trespalacios, O., King, M., Kamruzzaman, M., Haque, M.M., 2022. The influence of the built environment on pedestrians' perceptions of attractiveness, safety and security. Transport. Res. F Traffic Psychol. Behav. 87, 203–218.

Ben-Akiva, M., McFadden, D., Train, K., Walker, J., Bhat, C., Bierlaire, M., et al., 2002. Hybrid choice models: progress and challenges. Market. Lett. 13, 163–175.

Bliemer, M.C.J., Rose, J.M., 2009. Efficiency and sample size requirements for stated choice experiments. 88th Annual TRB Meeting. Washington, DC, January 2009, USA.

Bollen, K.A., 1989. Structural Equations with Latent Variables. John Wiley & Sons.

Calonge-Reillo, F., 2022. More fear, less walking: taking a walk in fortified housing environments in urban Mexico. J. Hous. Built Environ. 37 (1), 443–458.

Campisi, T., Tesoriere, G., Skoufas, A., Zeglis, D., Andronis, C., Basbas, S., 2022. Perceived pedestrian level of service: the case of Thessaloniki, Greece. Transport. Res. Procedia 60, 124–131.

Cantillo, V., Arellana, J., Rolong, M., 2015. Modelling pedestrian crossing behaviour in urban roads: a latent variable approach. Transport. Res. F Traffic Psychol. Behav. 32, 56–67.

Cantillo-García, V., Guzman, L.A., Arellana, J., 2019. Socioeconomic strata as proxy variable for household income in transportation research. evaluation for Bogotá, Medellín, Cali and Barranquilla. Dyna 86, 258–267.

Chica-Olmo, J., Sánchez, A., Sepúlveda-Murillo, F.H., 2020. Assessing Colombia's policy of socioeconomic stratification: an intra-city study of self-reported quality of life. Cities 97, 102560.

Cho, G., Rodríguez, D.A., Khattak, A.J., 2009. The role of the built environment in explaining relationships between perceived and actual pedestrian and bicyclist safety. Accid. Anal. Prev. 41 (4), 692–702.

DANE, 2018. Censo Nacional de Población y Vivienda 2018. Retrieved from. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018. (Accessed 16 September 2024).

de Bekker-Grob, Donkers, B., Jonker, M.F., Stolk, E.A., 2015. Sample size requirements for discrete-choice experiments in healthcare: a practical guide. The Patient-Patient-Centered Outcomes Research 8, 373–384.

Doulabi, S., Hassan, H.M., Ferguson, M.R., Razavi, S., Paez, A., 2021. Exploring the determinants of older adults' susceptibility to pedestrians' incidents. Accid. Anal. Prev. 155, 106100.

Ferreira, M.C., Costa, P.D., Abrantes, D., Hora, J., Felício, S., Coimbra, M., Dias, T.G., 2022. Identifying the determinants and understanding their effect on the perception of safety, security, and comfort by pedestrians and cyclists: a systematic review. Transport. Res. F Traffic Psychol. Behav. 91, 136–163.

Ferrer, S., Ruiz, T., 2018. The impact of the built environment on the decision to walk for short trips: evidence from two Spanish cities. Transport Pol. 67, 111–120.

Ferrer, S., Ruiz, T., Mars, L., 2015. A qualitative study on the role of the built environment for short walking trips. Transport. Res. F Traffic Psychol. Behav. 33, 141–160.

Financiera del Desarrollo Territorial., 2016. Santa Marta sostenible. Retrieved from. https://bibliotecadigital.findeter.metabiblioteca.com/handle/001/9620.

Fountas, G., Anastasopoulos, P.C., 2017. A random thresholds random parameters hierarchical ordered probit analysis of highway accident injury-severities. Analytic methods in accident research 15, 1–16.

Gebremariam, D., Kuhilen, T., Seboka, H., Grum, B., 2024. Effect of sidewalk design and obstructions on pedestrian mobility: a case study of the main streets of mekelle city, northern Ethiopia. Adv. Civ. Eng. 2024 (1), 5672280.

Georgiou, A., Skoufas, A., Basbas, S., 2021. Perceived Pedestrian Level of Service in an urban central network: the case of a medium size Greek city. Case Studies on Transport Policy 9 (2), 889–905.

Google, 2020. [Google Street View images from Bogotá, Medellín, Barranquilla, Santa Marta, Bucaramanga, and Valledupar, Colombia]. Retrieved July, 2020.

Guerrero, T.E., Guevara, C.A., Cherchi, E., Ortúzar, J. de D., 2022. Characterizing the impact of discrete indicators to correct for endogeneity in discrete choice models. Journal of Choice Modelling 42, 100342.

Guerrero, T.E., Avogadro, N., Ramos, R., 2024. Control Function Approach for Addressing Endogeneity in Transport Models: A Case Study on the London-Amsterdam Route. XV Congreso Colombiano de Transporte y Transito.
Gutiérrez, M., Cantillo, V., Arellana, J., Ortuzar, J. de D., 2021. Estimating bicycle demand in an aggressive environment. International Journal of Sustainable Transportation 15, 259–272.
Guzman, L.A., Arellana, J., Castro, W.F., 2022. Desirable streets for pedestrians: using a street-level index to assess walkability. Transport. Res. Transport Environ. 111, 103462.
Herrmann-Lunecke, M.G., Mora, R., Vejares, P., 2021. Perception of the built environment and walking in pericentral neighbourhoods in Santiago, Chile. Travel Behaviour and Society 23, 192–206.
Hurtubia, R., Guevara, A., Donoso, P., 2015. Using images to measure qualitative attributes of public spaces through sp surveys. Transport. Res. Procedia 11, 460–474.
Iglesias, P., Greene, M., Ortúzar, J. de D., 2013. On the perception of safety in low income neighbourhoods: using digital images in a stated choice experiment. Choice Modelling. The State of the Art and the State of Practice, pp. 193–210.
Larranaga, A.M., Arellana, J., Rizzi, L.I., Strambi, O., Cybis, H.B.B., 2019. Using best–worst scaling to identify barriers to walkability: a study of Porto Alegre, Brazil. Transportation 46, 2347–2379.
Le, T.P.L., Leung, A., Kavalchuk, I., Nguyen, H.N., 2021. Age-proofing a traffic saturated metropolis–evaluating the influences on walking behaviour in older adults in Ho Chi Minh city. Travel Behaviour and Society 23, 1–12.
Louviere, J.J., 2000. *Stated choice methods: analysis and applications*. Cambridge University Press.
Marks, M.M., Overall, C., 2015. Breaking down walls: new solutions for more effective urban crime prevention in South African Cities. Stability. International Journal of Security and Development 4 (1), 3-3.
Moscoso, M., van Laake, T., Quiñonez, L., 2019. Sustainable urban transport in Latin america assessment and recommendations for mobility policies. URL: https://sutp.org/publications/sustainable-urban-mobility-in-latin-america-assessment-and-recommendations-for-mobility-policies/.
Nag, D., Goswami, A.K., Gupta, A., Sen, J., 2020. Assessing urban sidewalk networks based on three constructs: a synthesis of pedestrian level of service literature. Transport Rev. 40, 204–240.
Narayanan, S., 2020. Pedestrian safety in Chennai. Journal of road safety 31, 15–32.
OMU, 2023. Indicadores – OMU – observatorio movilidad urbana. URL: https://omu-latam.org/indicadores/.
Orme, B., 1998. Sample size issues for conjoint analysis studies. Sequim: Sawtooth Software Technical Paper.
Ortúzar, J. de D., Willumsen, L.G., 2024. Modelling Transport. John Wiley & Sons, p. 5ed.
Park, Y., Garcia, M., 2020. Pedestrian safety perception and urban street settings. International Journal of Sustainable Transportation 14, 860–871.
Ramos, R., Cantillo, V., Arellana, J., Sarmiento, I., 2017. From restricting the use of cars by license plate numbers to congestion charging: analysis for Medellin, Colombia. Transport Pol. 60, 119–130.
Raveau, S., Yáñez, M.F., Ortúzar, J. de D., 2012. Practical and empirical identifiability of hybrid discrete choice models. Transp. Res. Part B Methodol. 46 (10), 1374–1383.
Rodriguez-Valencia, A., Barrero, G.A., Ortiz-Ramirez, H.A., Vallejo-Borda, J.A., 2020. Power of user perception on pedestrian quality of service. Transport. Res. Rec. 2674, 250–258.
Rossetti, T., Lobel, H., Rocco, V., Hurtubia, R., 2019. Explaining subjective perceptions of public spaces as a function of the built environment: a massive data approach. Landsc. Urban Plann. 181, 169–178.
Ruiz-Padillo, A., Oestreich, L., Torres, T.B., Rhoden, P.S., Larrañaga, A.M., Cybis, H.B., 2022. Weighted assessment of barriers to walking in small cities: a Brazilian case. Transport. Res. Transport Environ. 109, 103392.
Ruiz-Padillo, A., Pasqual, F.M., Uriarte, A.M.L., Cybis, H.B.B., 2018. Application of multi-criteria decision analysis methods for assessing walkability: a case study in Porto Alegre, Brazil. Transport. Res. Transport Environ. 63, 855–871.
Sriwastava, A., Reichert, P., 2023. Reducing sample size requirements by extending discrete choice experiments to indifference elicitation. J. Choice Model. 48, 100426.
Swanson, J., Pearmain, D., Loughead, K., 1992. Stated preference sample sizes. In: Transportation Planning Methods. Proceedings of Seminar e Held at the PTRC European Transport, Highways and Planning, 20th Summer Annual Meeting (September 14-18, 1992, p357. UMIST.
Serebrisky, T., Suárez-Alemán, A., Rivas, M.E., 2019. Stylized urban transportation facts in Latin America and the Caribbean. United Nations, 2018. World Urbanization Prospects - Population Division. URL: https://population.un.org/wup/.
Torres, T.B., Nodari, C.T., Larrañaga, A.M., 2024. Built environment and crash severity in school surroundings: a study of Porto Alegre, Brazil. Latin American transport studies 2, 100008.
TPD Ingeniería, Selfinve., NIPPON KOEI LAC, 2018. Estructuración técnica, legal y financiera del diseño de la integración del transporte público colectivo de pasajeros de Barranquilla y su Área Metropolitana y el sistema integrado de transporte masivo. Barranquilla.
United Nations, 2018. World urbanization prospects - population division. URL: https://population.un.org/wup/.
Vallejo-Borda, J.A., Cantillo, V., Rodriguez-Valencia, A., 2020. A perception-based cognitive map of the pedestrian perceived quality of service on urban sidewalks. Transport. Res. F Traffic Psychol. Behav. 73, 107–118.
Walker, J.L., 2001. Extended Discrete Choice Models: Integrated Framework, Flexible Error Structures, and Latent Variables. Doctoral dissertation, Massachusetts Institute of Technology.
Washington, S., Karlaftis, M.G., Mannering, F., Anastasopoulos, P., 2020. Statistical and Econometric Methods for Transportation Data Analysis, third ed. Chapman and Hall/CRC.
Yang, J.C., Johnson, F.R., Kilambi, V., Mohamed, A.F., 2015. Sample size and utility-difference precision in discrete-choice experiments: a meta-simulation approach. J. Choice Model. 16, 50–57.