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(Micro)mobility by electric scooters: psychometric assessment of the importance of built environment attributes to mode choice in Belo Horizonte

(Micro)mobilidade por patinetes elétricos: avaliação psicométrica da importância de atributos associados ao ambiente construído para a escolha de se utilizar o modo em Belo Horizonte

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ABSTRACT
The emergence of e-scooter (ES) sharing systems in Belo Horizonte, as well as in other urban centers around the world, has brought attention to a new way of getting around cities. While the occurrence of crashes involving micromobility vehicles is relatively small compared to the number of trips taken, it has sparked efforts from various stakeholders to understand how urban spaces can be optimized to maximize opportunities and minimize risks. This study focuses on evaluating the importance of built environment characteristics for individuals choosing to ride ES, according to the perception of those who are familiar with Belo Horizonte. Drawing from Bikeability indicators as a foundation, an online survey based on the Likert scale was applied. The results indicate that the predominant profile of ES users aligns with existing literature, consisting of young adult males with higher incomes and education levels. Although 82% of respondents expressed an interest in using ES, 61% noted that the city lacks the necessary conditions to support its operation. Utilizing the Method of Successive Intervals (MSI), the study identifies pavement condition and the presence of dedicated bike lanes as the most influential factors impacting ES usage.

RESUMO
O surgimento de programas de compartilhamento de patinetes elétricos (PEs) em Belo Horizonte – assim como em outros centros urbanos de todo o mundo, pôs em foco uma nova proposta de circular pelas cidades. A ocorrência de sinistros envolvendo o micromodo – ainda que proporcionalmente pequena em relação ao número de viagens realizadas, conduziu um esforço de diferentes atores em compreender como o espaço urbano deve ser otimizado de forma a maximizar oportunidades e minimizar riscos. O presente trabalho avalia a importância de características do ambiente construído na escolha de se utilizar o PE, segundo a percepção daqueles que conhecem Belo Horizonte. Partindo-se de indicadores de ciclabilidade, aplicou-se Questionário Online baseado em Escala Likert. Os resultados indicam que o perfil predominante do usuário de PE – homem, adulto jovem, alta renda e escolaridade, corresponde àquele observado na literatura. 82% consideram utilizar o modo, mas 61% apontam que a

cidade não apresenta as condições necessárias para sua operação. Pelo Método do Intervalos Sucessivos (MIS), verifica-se que os fatores mais importantes são a conservação do pavimento e a presença de rota cicloviária.

1. INTRODUCTION

The production of transportation in Brazil has historically prioritized the development of automobile-centric spaces, leading to poorly planned urban environments marked by inequalities, particularly affecting vulnerable groups such as pedestrians, cyclists, and public transport users (Cardoso, 2007). These deficiencies in urban mobility have resulted in negative effects, both locally and globally, including congestion, urban diseconomies, social space degradation, and risks to public health.

Consequently, cities have become dehumanized (Jacobs, 2011). To counter these issues, the concept of sustainable mobility has emerged, aiming to create more humane and democratic cities by promoting population density, mixed land use, and reducing travel distances to optimize urban space utilization (Bannister, 2007).

Advancements in technology have introduced new possibilities for urban mobility, offering solutions to improve people's lives. Within these innovations, new proposals for urban mobility have emerged (Queiroz, 2020). Lyons (2018) suggests that future transportation can develop in different ways, such as new propulsion and vehicle control system, changes in the economic model of vehicle ownership and usage, mobile technologies empowering citizens in decision-making, and opportunities to engage in activities without the need for physical travel. However, concepts such as smart mobility and shared mobility are still incipient in national transport planning, with limited propositions and actions, as noted by Lucchesi et al. (2019).

Amidst a paradigm shift driven by technology in transportation (McKenzie, 2019), there has been significant growth in ride-sharing services, autonomous vehicles, and more recently, the sharing of electric scooters (ES) in major urban centers worldwide. ES, considered part of the micromobility urban phenomenon, provide an alternative for first and last-mile trips and short journeys for various purposes (Aasebo, 2019).

The rapid implementation of ES in urban centers, often without proper alignment with municipalities, has made it challenging to assess their impacts on other mobility services, citizen safety, and the establishment of appropriate regulation (Herrman, 2019). Consequently, the limited knowledge regarding this mode of transportation can lead to suboptimal decision-making and missed opportunities for sustainable management of sharing programs.

Observing the evolutionary process of bike-sharing over five generations, it becomes evident that the system has undergone transformations, particularly in terms of operational and safety aspects, driven by technology (Shaheen, Guzman and Zhang, 2010). Similarly, it is expected, therefore, that the ES sharing system will also undergo adaptations, especially in light of the reflections brought about by the COVID-19 pandemic. The consequences of the rapid spread of the disease have raised questions about how people travel and interact with space. Many of these have translated into positive mobility strategies, such as traffic calming measures, temporary cycling network, and free bike-sharing (NACTO, 2020).

This context has prompted cities to reconsider their infrastructure to accommodate new modes of Transportation like ES. In this regard, focusing on the city of Belo Horizonte, this study aims to identify the built environment characteristics that are important to potential micromobility users. The findings can contribute to the decision-making process of micromobility companies seeking to resctrucutre their sharing systems effectively, as well as urban planners in regulating the mode and proposing interventions in the built environment.

2. BUILT ENVIRONMENT AND E-SCOOTERS

The built environment, as defined by Heinen, Maat and Van Wee (2011), represents the spatial context of a neighborhood, city, or specific region. It encompasses the urban infrastructure shaped by human actions, including elements of urban configuration such as population density, land use characteristics, road connectivity, and road network layout (Handy et al., 2002). Platt and Rybarczyk (20201) argue that this infrastructure should be (re)planned to accommodate emerging and non-traditional uses of space, such as new forms of micromobility vehicles like skateboards and ES.

Various aspects of the built environment can influence transportation behavior, affecting travel demand, mode choice, and even the selected route (Cervero and Kockelman, 1997). When a trip is comfortable and safe for riders, the are more likely to repeat the same route and mode (St-Louis et al., 2014). However, the production of space, by conventional transport planning approaches, has resulted in a rigid landscape that perpetuates inequities in spatial use, particularly affecting active transportation modes and micromobility riders. Therefore, it is necessary to evaluate which factors related to the built environment are deemed most important from the perspective of potential users for the adoption of micromobility, offering guidance for future urban interventions. The development of walkability and bikeability indexes has proven valuable for assessing the suitability of spaces for walking and cycling (Barros et al., 2021; Bagno et al., 2019).

According to Carvalho (2018), an index is composed by indicators capable of quantifying aspects of social or built reality, enabling the analysis of trends and contexts to support in the decision-making processes. Segnestam (2002) points out that there is not a single set of indicators, but different combinations that should align with the intended evaluation concept, as highlighted by Januzzi (2002). Incorporating user perception into the attribute selection process during index construction can lead to evaluations that are more tailored to the specificities of the study area, as the results reflect the preferences of potential users of the targeted mode (Barros et al., 2021).

However, the literature still lack sufficient evidence regarding the correlation between the attributes of the built environment and the use of ES. In general, studies conducted by Matthew et al. (2019), McKenzie (2019), Jiao and Bai (2020), and Reck, Guidon and Axhausen (2020) have found a significant connection between micromobility riding and certain characteristics such as proximity to the city center and universities, well-connected streets, and mixed land use.

Ewing and Cervero (2010) highlight the most common approach found in the literature to describe the influences of the built environment on travel demand which is through the 5D Model. The five dimensions presented in the model are density, diversity, design, destination accessibility, and distance to transit. While this model predominantly characterizes at a regional level, Platt and Rybarczyk (2021) emphasize the importance of an analysis focused on street scale. Therefore, considerations should also be given to infrastructure designated to micromobility (e.g., cycling ways, surface type and maintenance, physical separators, parking, and horizontal/vertical signage) and supporting urban infrastructure (e.g., street lighting and urban drainage).

3. METHODOLOGY

Given the limited number of studies exploring the relationship between the built environment to the use of ES (Jiao and Bai, 2020), it is necessary to select attributes based on bikeability indicators, as cycling infrastructure is commonly preferred by micromobility riders (Bruxelles, 2019; Fitt and Curl, 2019). National regulations have also recognized cycling network (cycle paths, bike lanes, and bike routes) as suitable spaces for micromode circulation in cities (Belo Horizonte, 2021; Rio de Janeiro, 2019; São Paulo, 2019).

Therefore, this study initially relies on the work of Bagno et al. (2019) who compiled the 39 most frequently mentioned bikeability indicators from national and international literature. Their goal was to develop a Bikeability Index to assess cyclability in the capital city of Minas Gerais, considering the significance attributed to these indicators by the citizens of Belo Horizonte. From this set of attributes, the 5D Model proposed by Ewing and Cervero (2010) is utilized as a criterion to select the attributes associated with the built environment. The chosen attributes encompass urban configuration, cycling infrastructure, and supporting urban infrastructure, while excluding those categorized as traffic, individual, or natural attributes, despite their relative importance in related studies. The study presents the 21 selected attributes, along with the methodological steps, as depicted in Figure 1.

To assess the 21 selected attributes, a questionnaire was developed to collect information about the perception of potential ES riders in Belo Horizonte. The survey consisted of two parts. The first part included questions related to the respondents' socioeconomic profile (e.g., gender, age, education, and monthly household income) as well as their primary modes of transportation. Participants were then asked whether they had previously ridden an ES and how frequently they would use it in a scenario with improved conditions. Those who expressed a willingness to use the mode frequently in a hypothetical scenario evaluated the importance of the 21 selected attributes using five-point Likert scale. The Likert scale widely used in opinion surveys, allows respondents to indicate their level of agreement with a given statement (Ferreira et al., 2017).

Due to the restrictions imposed by the COVID-19 pandemic, the questionnaire was exclusively administered online. The collected data were analyzed using descriptive statistics, Cronbach's alpha, and the Successive Intervals Method (SIM). Descriptive statistics allow identifying the prevalence of opinions regarding a particular perception (Barros et al., 2021). For example, the 3rd quartile represents the value at the 75th percentile of the ordered sample, or the value from which the top 25% of values are derived.

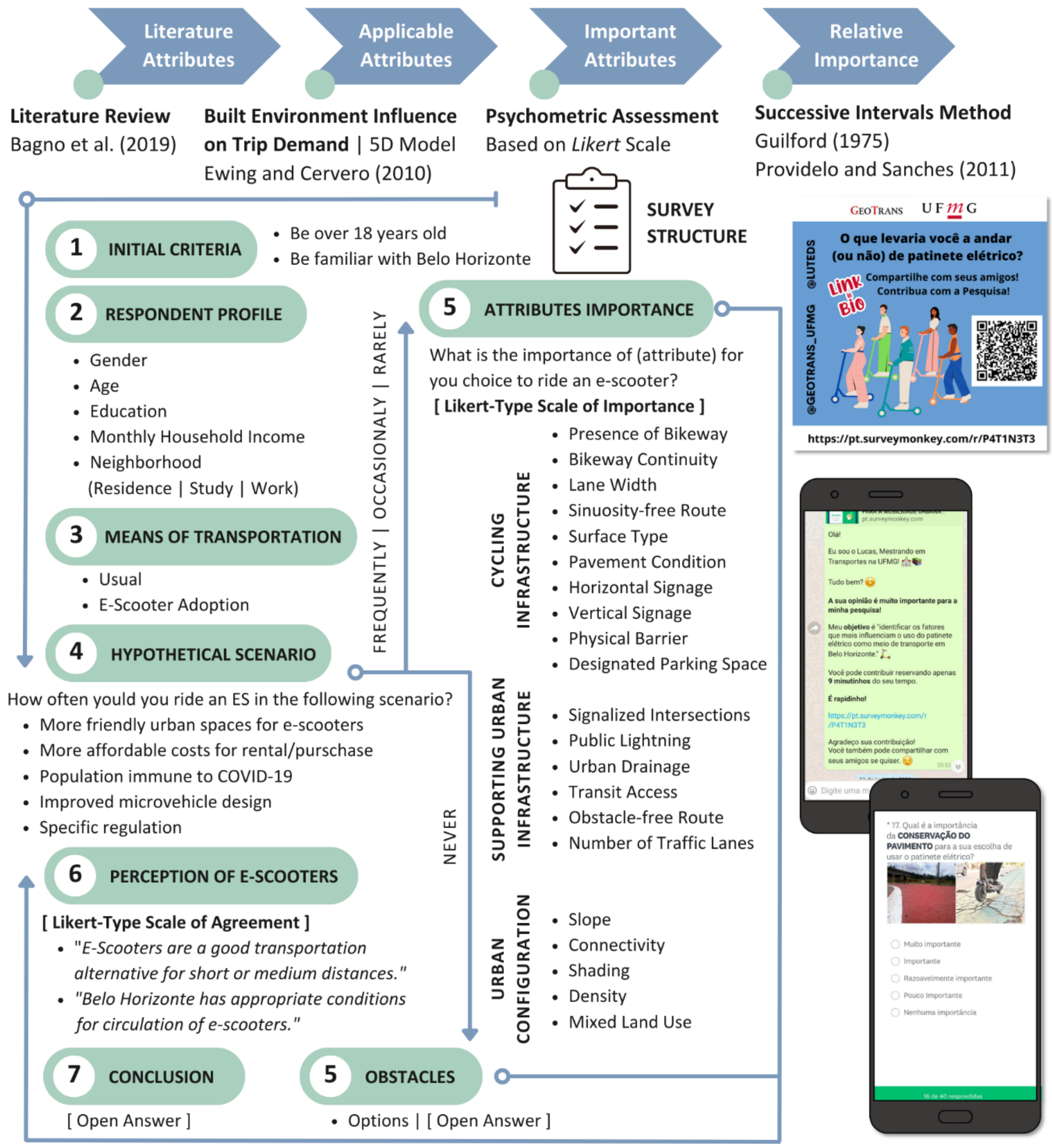

Figure 1. Methodological steps and survey structure.

Cronbach's alpha is employed to assess the reliability of respondents' answers, providing an important step in validating the discussion on the most significant attributes (Barros et al., 2021). A coefficient above 0.7 is generally considered acceptable, indicating good internal consistency (Hora, Monteiro and Arica, 2010). Descriptive statistics and Cronbach's alpha are calculated using the statistical software R Studio (R Language).

Finally, the Successive Intervals Method (SIM) is applied to identify the most important attributes for potential riders in Belo Horizonte. Developed by Guilford (1975), this method is based on psychometric scales and allows for estimating individual perception by assessing the relative importance of different characteristics (Barros et al., 2021). The SIM has been used in other transportation research studies, including those conducted by Barros et al. (2021) to identify the most important walkability attributes from the perspective of pedestrians in Belo Horizonte, by Diniz (2017) to assign weights to qualities of public transportation from the perspective of motorized individual transport users, and by Providelo and Sanches (2011) to assess which characteristics are prioritized by bicycle riders and potential ones regarding the quality of traffic lanes for cycling.

4. RESULTS AND DISCUSSION

4.1. Profile of respondents

The online questionnaire was conducted in July 2021 using the Survey Monkey platform and was distributed through Instagram and WhatsApp. A total of 671 responses were collected from individuals who fulfilled the initial criteria of being over 18 years old and having familiarity with Belo Horizonte. An overview of the results is provided in Table 1.

It is important to note that non-residents of the state capital were also included in the study, as long as they were familiar with the city. This was done to increase the number of respondents, particularly those who have previously ridden an e-scooter (ES), considering the limited availability of this mode of transportation in Belo Horizonte. ES rentals were only available in certain areas of the city between January 2019 and January 2020. Therefore, the aim was to identify the perception of a more representative sample of potential riders who have prior knowledge of how an ES system functions. The estimated sample confidence level was 99% with a margin of error of 5%.

Table 1: Profile of respondents

	Overall[2]		Have ridden an ES[3]		
Answers	**N**	**%**	**N**	**%**	**% Relative**
Male	267	40%	84	54%	31%
Female	400	60%	73	46%	18%
Non-binary	4	1%	-	-	
18 a 29 y/o	300	45%	84	54%	27%
30 a 39 y/o	212	32%	55	35%	
40 a 49 y/o	90	13%	16	10%	14%
50 a 59 y/o	42	6%	2	1%	
60 y/o or older	27	4%	0	0%	0%
None	-	-	-	-	-
Incomplete primary education	4	1%	-	-	-
Complete primary education	2	0%	-	-	
Incomplete secondary education	9	1%	1	1%	5%
Complete secondary education	52	8%	2	1%	
Incomplete higher education	182	27%	46	29%	25%
Complete higher education	159	24%	39	25%	
Incomplete graduate education	52	8%	16	10%	26%
Complete graduate education	211	31%	53	34%	
Up to 2 minimum wages[1]	116	17%	13	8%	11%
Above 2 to 4 minimum wages[1]	148	22%	31	20%	21%
Above 4 to 10 minimum wages[1]	269	40%	65	41%	24%
Above 10 to 20 minimum wages[1]	105	16%	37	24%	35%
Above 20 minimum wages[1]	33	5%	11	7%	33%

[1]Minimum wage in 2021 was R$ 1,100.00.
[2]Total of 671 respondents.
[3]Total of 157 respondents.

The respondents are predominantly women (60%), young adults (76%), with complete higher education (63%), and a monthly household income above four to ten minimum wages (40%). The lower proportion of individuals with lower income, limited education and/or advanced age reflects the limitation of the online application and can be justified by limited internet access, as well as a possible lack of digital familiarity (CETIC, 2018).

The main modes of transportation used by the respondents for daily commutes were car (66%), bus (61%), ride-hailing services (50%), and walking (48%). Regarding micromobility, we observed lower proportions in the use of personal bicycles (5%), shared bicycles (2%), ES (1%), and skateboards (one respondent). It is important to note that the ES sharing systems were discontinued in Belo Horizonte in early 2020, which may indicate that a small percentage of respondents possibly commute frequently using their own ES, finding them practical for use (in addition to fun and leisure). The relatively low utilization of micromodes, especially ES, does not reduce the responsibility of the municipalities to pay attention to the particularities of these modes of transportation and the demands from riders and non-riders regarding their safe integration into cities.

Among the respondents who have previously ridden an ES, the majority were men (54%), young adults (89%), with completed higher education (69%), and a monthly household income above four to ten minimum wages (41%). The socioeconomic profile aligns with findings from Bruxelles (2019), Fitt and Curl (2019), and Orr, MacArthur and Dill (2019). Despite the consequent sampling bias resulting from the limitations of the online survey, the analysis of the results regarding the importance of attributes and perceptions about ES remains valid since the socioeconomic profile of the participants is similar to that of potential micromobility riders, in line with the literature. However, it is important to acknowledge that the opinions of minority segments identified in the research should not be disregarded. Nonetheless, for a broader target audience, an in-person survey would be essential, although this was not feasible due to the ongoing pandemic.

The analysis of relative percentages allows us to presume that a higher use of ES is directly linked to the male gender, higher education and income, and inversely related to age. The lower propensity of the female audience to ride micromobility as a means of transportation can be justified (analogously) by insecurity resulting from sociocultural issues, as pointed out by Viola (2017), regarding the use of bicycles. The reasons that possibly justify the significant proportion of young adults are greater digital familiarity and significant access/use of credit/debit cards (CETIC, 2018) - requirements for renting micromobility devices - as well as greater skill in operating microvehicles (Fitt and Curl, 2019). On the other hand, the high prices charged by micromobility startups may hinder or make it difficult for marginalized social groups to access the alternative mode. The high prices can be partially justified by the costly logistics and maintenance of equipment, given the relatively short lifespan of ES – approximately 28 days (Hollingsworth, Copeland and Johnson, 2019). The unsustainable market model led to the closure of some micromobility companies, requiring a restructuring of its proposal.

4.2. Perception about e-scooters

When considering a hypothetical scenario characterized by a more friendly urban space for electric scooter (ES) circulation, improved microvehicle design, affordable rental/purchase costs, specific regulations, and a population immune to COVID-19, a significant inclination towards using micromobility as a mode of transportation was observed among the respondents, as presented in Table 2.

Among the respondents who have already ridden ES (23%), a larger proportion would use them occasionally (36%) or frequently (31%). This finding suggests a shift in perception after the initial experience, where micromobility is seen not only as a source of fun or leisure but also as a convenient and faster alternative for short trips, as highlighted by Fitt and Curl (2019).

Table 2: Choice to ride an e-scooter in a hypothetical scenario and perception about the mode

Answers	Overall[1]		Have you ever ridden an ES?			
		%	YES[2]	%	NO	%
Never	118	18%	7	4%	111	22%
Rarely (once to 3x a year)	187	28%	46	29%	141	27%
Occasionally (once to 3x a month)	175	26%	56	36%	119	23%
Frequently (at least once a week)	191	28%	48	31%	143	28%
Q1 - Is an e-scooter a good transportation alternative for short and medium distances?						
Totally agree	301	45%	71	45%	230	45%
Partly agree	258	38%	62	39%	196	38%
Neutral	61	9%	10	6%	51	10%
Partly disagree	34	5%	12	8%	22	4%
Totally disagree	17	3%	2	1%	15	3%
Q2 - Does the city of Belo Horizonte have the necessary conditions for the adoption of e-scooter?						
Totally agree	43	6%	12	8%	31	6%
Partly agree	148	22%	40	25%	108	21%
Neutral	68	10%	14	9%	54	11%
Partly disagree	233	35%	50	32%	183	36%
Totally disagree	179	27%	41	26%	138	27%

[1]Minimum wage in 2021 was R$ 1,100.00.
[2]Total of 671 respondents.
[3]Total of 157 respondents.

However, 18% of the respondents indicated that they would never use the microvehicle. The main reason cited was a feeling of insecurity (75%), followed by lack of interest (25%), and high costs for purchase/rental (10%). This finding aligns with the research of Bruxelles (2019), Fitt and Curl (2019), and Orr, MacArthur and Dill (2019), who also identified insecurity as a major obstacle to the adoption of micromobility. Furthermore, it is important to emphasize the proportion of respondents who mentioned not using ES due to their high cost. Considering the socioeconomic profile of the sample, it is essential to emphasize once again the determining role of cost in modal choice. Despite the significant interest in using ES expressed by a portion of the respondents, the persistently high rental/purchase costs may impede the experimentation of this alternative mode of transportation and hinder the gradual shift in perceptions regarding its potential advantages.

The respondents also mentioned other reasons for not using ES. In general, their comments reaffirm the feeling of insecurity. The respondents perceive the mode as "dangerous" and expressed "fear of accidents and falls". Insecurity was also related to the design of the vehicles, which "do not guarantee stability" and have "small and solid wheels, unable to overcome pavement imperfections". This characteristic also suggests little comfort during the journey due to vibration/shaking. Participants also pointed out the topography as an obstacle as some questioned the performance of ES in hilly areas of the city. Another limitation mentioned by one of the respondents is the "difficulty of carrying bags and packages" while riding the vehicle. Additionally, some participants reported "never having seen ES", "rarely going to Belo Horizonte" or "not having access to the mode where they live/work". Lastly, the "lack of appropriate infrastructure (including streets, bikeways and sidewalks)" was cited as a reason for not adopting this mode.

Regarding the perception of the respondents about ES, we found that 83% agree (totally or partially) that ES are a good transportation alternative for short and medium distances. However, 62% disagree (totally or partially) that Belo Horizonte has appropriate conditions for circulation of ES. The positive acceptance of micromobility as a means of transportation, combined with an urban space that is poorly prepared to accommodate it, according to the perception of potential riders, demonstrates the importance of considering the specificities of new mobility proposals in urban (re)planning, making the built environment inviting, accessible and safe. However, infrastructural (re)structuring represents only a set of guidelines that should be linked to a broader strategy involving the regulation of ES, public awareness campaigns (including safe driving training), and fair pricing strategies that cater to different socioeconomic groups.

4.3. Importance of attributes

The respondents who indicated that they rarely, occasionally, or frequently ride the e-scooter (ES) in a hypothetical scenario, accounting for 82% (553), were asked to assess the level of importance for each of the 21 attributes associated with the built environment using the Likert scale. Table 7 displays the frequencies of responses for each attribute's category of importance.

To assess the relative importance among the attributes, the Successive Intervals Method (SIM), developed by (Guilford, 1975), was applied. The calculation process developed below was based on Providelo and Sanches (2011). According to these authors, SIM assumes that the variable related to individuals' choices follows a normal probability distribution. Thus, the values of the categories (importance levels) can be estimated based on the observed frequencies, corresponding to different segments along a standard normal curve. As an illustration, Figure 2 illustrates the observed frequencies (p_j) for the attribute "Connectivity". About 27% (150 out of 553) of the respondents (hatched area) stated that this attribute is important in their decision to ride an ES.

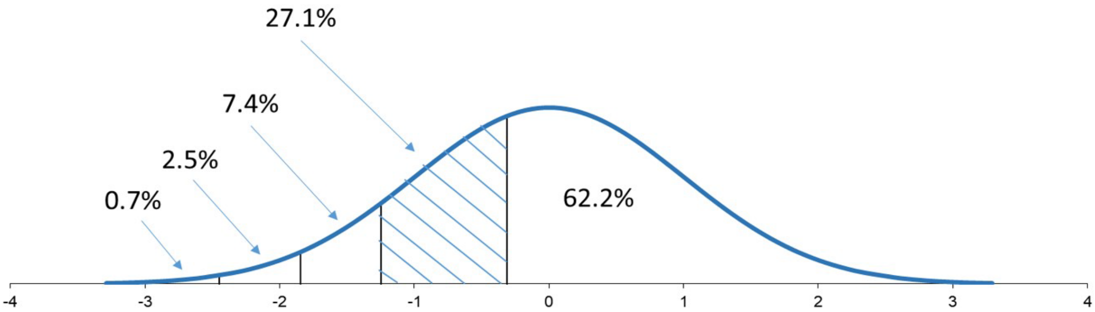

Figure 2: Relative frequency of the attribute Connectivity

Thus, the relative frequency (p_j) is calculated by Equation 1.

$$p_j = \frac{f_j}{\sum f} \quad (1)$$

For example:

$$P_4(A_{Connectivity}) = \frac{f_4}{\sum f} \rightarrow p_4(A_{Connectivity}) = \frac{150}{553} = 0.2712$$

Next, the accumulated frequency of the category (P_j) is calculated, which represents the cumulative sum of the relative frequencies (p_j) for all previous categories up to the current category.

For example:

$$P_4(A_{Connectivity}) = p_1 + p_2 + p_3 + p_4 = 0.0072 + 0.0253 + 0.0741 + 0.2712 = 0.3779$$

To calculate the lower limit ($z1_j$) and upper limit ($z2_j$) of each category (variables indicated in Figure 3), the "INV.NORMP.N" function of Microsoft Excel 2016 software is used. This function is applied, respectively, to the accumulated frequency of the previous category (P_{j-1}) and the accumulated frequency of the current category (P_j). The "INV.NORM.P" function returns the inverse of the standard normal cumulative distribution, with a mean of 0 (zero) and a standard deviation of 1 (one).

For example:

$$z1_4(A_{Connectivity}) = INV.NORMP.N(P_3) = INV.NORMP.N(0.1067) = -1.2443$$

$$z2_4(A_{Connectivity}) = INV.NORMP.N(P_4) = INV.NORMP.N(0.3779) = -0.3109$$

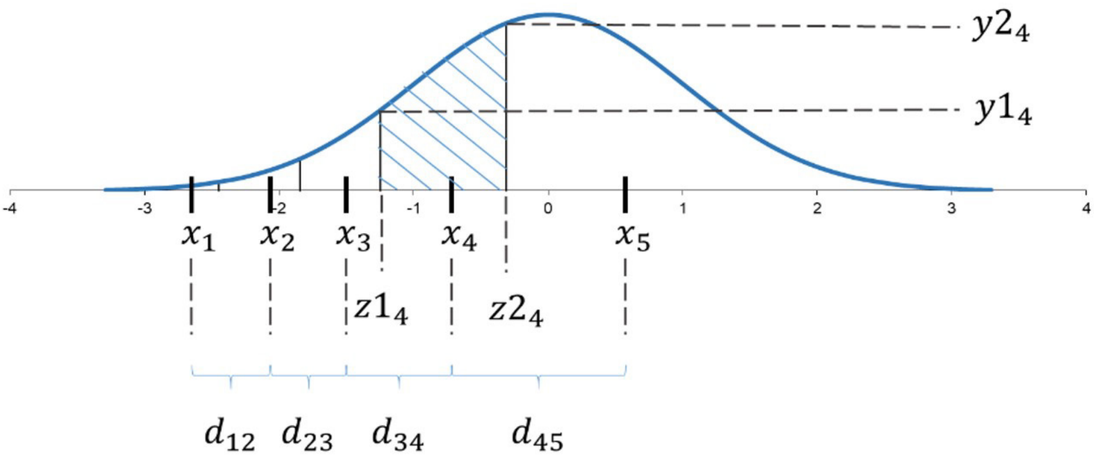

Figure 3. Parameters indicated on the standard normal curve

To calculate the ordinate of the lower limit of the category ($y1_j$) and the ordinate of the upper limit of the category ($y2_j$) (variables indicated in Figure 3), Equations 2 and 3 are used.

$$y1_j = \frac{1}{\sqrt{2 \times \pi}} \times e^{-0,5 \times (Z1_j)^2} \tag{2}$$

$$y2_j = \frac{1}{\sqrt{2 \times \pi}} \times e^{-0,5 \times (Z2_j)^2} \tag{3}$$

For example:

$$y1_4(A_{Connectivity}) = \frac{1}{\sqrt{2 \times \pi}} \times e^{-0,5 \times (-1,2443)^2} = 0.1839$$

$$y2_4(A_{Connectivity}) = \frac{1}{\sqrt{2 \times \pi}} \times e^{-0,5 \times (-0,3109)^2} = 0.3801$$

Once the ordinates of the lower limit ($y1_j$) and upper limit ($y2_j$) of each category are calculated, the estimated values of the category (x_j) (variable indicated in Figure 3) can be obtained using Equation 4.

$$x_j = \frac{y1_j - y2_j}{p_j} \tag{4}$$

For example:

$$x_4(A_{Connectivity}) = \frac{y1_4 - y2_4}{p_4} = \frac{(0.1839 - 0.3801)}{0.2712} = -0.7232$$

The Table 3 presents the results for the five categories of the attribute “Connectivity”. The estimated values for the categories (x_j) for all 21 attributes are presented in Table 4.

Table 3: Estimation of category values related to the attribute Connectivity

Statistical Parameters	Categories				
	1	**2**	**3**	**4**	**5**
Frequency (f_j)	4	14	41	150	344
Relative frequency (p_j)	0.0072	0.0253	0.0741	0.2712	0.6221
Accumulated frequency (P_j)	0.0072	0.0325	0.1067	0.3779	1.0000
Lower limit of the category (z_1)	-∞	-2.4455	-1.8446	-1.2443	-0.3109
Upper limit of the category (z_2)	-2.4455	-1.8446	-1.2443	-0.3109	∞
Ordenate of lower limit of the category (y_1)	0.0000	0.0201	0.0728	0.1839	0.3801
Ordenate of upper limit of the category (y_2)	0.0201	0.0728	0.1839	0.3801	0.0000
Estimated value of the category (x_j)	-2.7731	-2.0829	-1.4993	-0.7232	0.6111
Distance between categories (d_j↔j+1)	0.0000	0.6902	0.5837	0.7760	1.3343

1: Not at all important. 2: Slightly important. 3: Moderately important. 4: Important. 5: Very important.

When plotting the estimated values of the categories (x_j), it becomes evident that the successive distances between them are not equal (as indicated in Figure 3). For instance, the distance between categories 4 and 5 (d_{45}) (1.3343) is greater than the distance between categories 3 and 4 (d_{34}) (0.7760). These discrepancies clearly indicate the inaccuracy in assigning integer values (1, 2, 3, 4, 5) to the categories, assuming equal distances between them. To address this issue, the distances between categories ($d_{j\leftrightarrow j+1}$) are then calculated using Equation 5 and presented in Table 5 for all 21 attributes.

$$d_{j\leftrightarrow j+1} = x_{j+1} - x_j \quad (5)$$

For example:

$$d_{45}(A_{Connectivity}) = x_5 - x_4 = 0.6111 - (-0.7232) = 1.3343$$

According to Guilford (1975), to ensure that all attributes are evaluated simultaneously on a common scale, it is suggested to obtain an appropriate scale (reference scale) (Equation 7) by taking into account the average distance between the categories (calculated using Equation 6).

$$Average_{j\leftrightarrow j+1} = Average(d_{j\leftrightarrow j+1})_{A1\leftrightarrow A21} \quad (6)$$

For example:

$$Average_{45} = Average(d_{45})_{A1\leftrightarrow A21} = \frac{d_{45_{A1}} + \cdots + d_{45_{A21}}}{21} = \frac{0.9834 + \cdots + 1.0464}{21} = 1.2178$$

Table 4: Estimated values for the categories (x_j)

Attributes	Estimated values for the categories (x_j)				
	1	2	3	4	5
Pavement Condition	-2.8661	-2.4943	-1.8577	-0.9864	0.4627
Presence of Bikeway	-2.7731	-2.3019	-1.7541	-1.0836	0.3752
Surface Type	-2.8661	-2.3104	-1.6350	-0.8461	0.5207
Signalized Intersections	-2.8661	-2.2567	-1.6198	-0.8772	0.4970
Street Lighting	-2.7731	-2.2736	-1.7317	-0.8516	0.5578
Urban Drainage	-2.6992	-2.1496	-1.6751	-0.9466	0.4732
Connectivity	-2.7731	-2.0829	-1.4993	-0.7232	0.6111
Obstacle-free Route	-2.8661	-2.0445	-1.3933	-0.7012	0.5897
Bikeway Continuity	-2.6992	-1.9179	-1.3627	-0.6942	0.6030
Horizontal Signage	-2.9928	-2.0272	-1.2655	-0.4996	0.7312
Physical Barrier	-2.6375	-1.8226	-1.2033	-0.5466	0.6760
Lane Width	-2.5375	-1.8326	-1.1998	-0.5069	0.7007
Vertical Signage	-2.7731	-1.7431	-1.0077	-0.3044	0.8461
Transit Access	-2.4229	-1.6897	-1.0994	-0.4108	0.7764
Designated Parking Space	-2.3068	-1.4883	-0.9019	-0.2536	0.8791
Number of Traffic Lanes	-2.4577	-1.4692	-0.7463	-0.0419	1.0429
Slope	-2.3330	-1.3312	-0.5538	0.1252	1.1248
Sinuosity-free Route	-2.3330	-1.2455	-0.4952	0.1085	1.0920
Mixed Land Use	-2.0145	-1.2040	-0.5753	0.1238	1.1701
Density	-2.1947	-1.3024	-0.5373	0.2478	1.2896
Shading	-1.8211	-0.8616	-0.0976	0.5757	1.4607

1: Not at all important. 2: Slightly important. 3: Moderately important. 4: Important. 5: Very important.

To find the reference scale (accumulated) ($ERAC_{j\leftrightarrow j+1}$), Equation 7 is applied.

$$ERAC_{j\leftrightarrow j+1} = average(d_{j\leftrightarrow j+1})_{A1\leftrightarrow A21} + ERAC_{j-1\leftrightarrow j} \quad (7)$$

For example:

$$ERAC_{45} = average(d_{45})_{A1 \leftrightarrow A21} + ERAC_{34} = 1.2178 + 2.1374 = 3.3565$$

The values of the average distances between categories and the reference scales (accumulated) are highlighted in Table 5.

Thus, the differences between the reference scale (accumulated) (as shown in Table 5) and the estimated values for the categories (Table 4) are calculated. The differences for each of the 21 attributes are presented in Table 6.

Example for the attribute "Connectivity":

$$\text{Difference btw scales}_{5(A_{Connectivity})} = ERAC_{45} - x_{5(A_{Connectivity})} = 3.3565 - 0.6111 = 2.7454$$

Table 5: Distance between the categories ($d_{j\leftrightarrow j+1}$)

Attributes	Distance between the categories ($d_{j\leftrightarrow j+1}$)			
	d12	**d23**	**d34**	**d45**
Pavement Condition	0.3717	0.6367	0.8713	1.4490
Presence of Bikeway	0.4712	0.5478	0.6705	1.4588
Surface Type	0.5556	0.6754	0.7889	1.3668
Signalized Intersections	0.6093	0.6369	0.7425	1.3742
Street lighting	0.4995	0.5420	0.8801	1.4093
Urban Drainage	0.5496	0.4745	0.7285	1.4198
Connectivity	0.6902	0.5837	0.7760	1.3343
Obstacle-free Route	0.8216	0.6512	0.6921	1.2909
Bikeway Continuity	0.7812	0.5553	0.6684	1.2972
Horizontal Signage	0.9656	0.7618	0.7659	1.2308
Physical Barrier	0.8149	0.6193	0.6567	1.2226
Lane Width	0.7050	0.6327	0.6929	1.2076
Vertical Signage	1.0300	0.7354	0.7033	1.1505
Transit Access	0.7332	0.5904	0.6886	1.1872
Designated Parking Space	0.8185	0.5863	0.6484	1.1327
Number of Traffic Lanes	0.9885	0.7229	0.7044	1.0849
Slope	1.0018	0.7774	0.6790	0.9996
Sinuosity-free Route	1.0875	0.7503	0.6038	0.9834
Mixed Land Use	0.8104	0.6287	0.6991	1.0464
Density	0.8923	0.7651	0.7851	1.0418
Shading	0.9595	0.7640	0.6733	0.8850
Average $d_{j\leftrightarrow j+1}$ (Column)	0.7694	0.6494	0.7199	1.2178
Reference Scale (Accumulated) ($ERAC_{j\leftrightarrow j+1}$)	0.7694	1.4188	2.1387	3.3565

The values on the last column on the right side of Table 6 corresponds to the average between the diferences calculated previously. The higher the average value, the higher the importance of the attribute (Providelo and Sanches, 2011).

In order to facilitate data analysis, the differences between scales (averages presented in Table 6) can be converted into a range from 0 to 1, using Equation 8 (Providelo and Sanches, 2011).

$$m'_{A(n)} = \frac{m_{A(n)} - \min(m)_{A1 \leftrightarrow A21}}{\max(m)_{A1 \leftrightarrow A21} - \min(m)_{A1 \leftrightarrow A21}} \quad (8)$$

For example:

$$m'_{A(Connectivity)} = \frac{2.8302 - 1.6855}{3.0850 - 1.6855} = 0.82$$

Table 6: Differences between each category's scale and the reference scale

Attributes	Differences between scales					
	1	2	3	4	5	Average
Pavement Condition	2.8661	3.2637	3.2765	3.1251	2.8938	3.0850
Presence of Bikeway	2.7731	3.0713	3.1729	3.2223	2.9813	3.0442
Surface Type	2.8661	3.0798	3.0538	2.9848	2.8358	2.9641
Signalized Intersections	2.8661	3.0261	3.0386	3.0160	2.8595	2.9613
Street Lighting	2.7731	3.0430	3.1505	2.9903	2.7987	2.9511
Urban Drainage	2.6992	2.9190	3.0939	3.0853	2.8833	2.9361
Connectivity	2.7731	2.8523	2.9181	2.8620	2.7454	2.8302
Obstacle-free Route	2.8661	2.8139	2.8121	2.8400	2.7668	2.8198
Bikeway Continuity	2.6992	2.6873	2.7815	2.8330	2.7535	2.7509
Horizontal Signage	2.9928	2.7966	2.6843	2.6383	2.6253	2.7475
Physical Barrier	2.6375	2.5920	2.6221	2.6854	2.6805	2.6435
Lane Width	2.5375	2.6019	2.6186	2.6457	2.6558	2.6119
Vertical Signage	2.7731	2.5125	2.4265	2.4431	2.5104	2.5331
Transit Access	2.4229	2.4591	2.5182	2.5496	2.5801	2.5060
Designated Parking Space	2.3068	2.2577	2.3208	2.3923	2.4774	2.3510
Number of Traffic Lanes	2.4577	2.2386	2.1651	2.1807	2.3136	2.2711
Slope	2.3330	2.1006	1.9726	2.0136	2.2317	2.1303
Sinuosity-free Route	2.3330	2.0149	1.9140	2.0302	2.2645	2.1113
Mixed Land Use	2.0145	1.9734	1.9941	2.0150	2.1864	2.0367
Density	2.1947	2.0718	1.9561	1.8909	2.0669	2.0361
Shading	1.8211	1.6310	1.5164	1.5631	1.8958	1.6855

1: Not at all important. 2: Slightly important. 3: Moderately important. 4: Important. 5: Very important.

As a result, the relative importance for each of the 21 evaluated attributes is presented on a scale of 0 to 1 in which the atribute with score 1.00 is considered the most importante and the atribute with the score 0.00 is the least important (Table 7).

By using the alpha command in the R Language, available in the psych library, the Cronbach's alpha obtained was 0.91, indicating the consistency of the participants' responses and validating the application of SIM. The statistical description of the sample continues with the Summary command in the R software, which returns the minimum and maximum values, as well as the median, 1st, and 3rd quartiles of the sample for each attribute, also presented in Table 7.

It can be observed that the respondents consider "Pavement Condition" (1.00) as the most important attribute related to the built environment for choosing to ride an ES, followed by "Presence of Bikeway" (0.97), "Surface Type" (0.91), "Signalized Intersections" (0.91), and "Street Lighting" (0.91). These results, particularly regarding pavement quality, emphasize the importance of considering the specificities of emerging micromobility in the construction/adaptation of dedicated infrastructure. Unlike bicycles, ES - commonly equipped with small solid wheels - present more challenges when circulating in cities, making it difficult or impossible to overcome surface imperfections. Thus, different types of pathologies (e.g., cracks, potholes, joints, steps) can make the journey uncomfortable and/or pose risks to riders' safety.

Table 7: Descriptive summary of attributes

Attributes	Descriptive Analysys					Answer Frequency					Relative Importance
	Min	1ºQ	Med	3ºQ	Max	1	2	3	4	5	
Pavement Condition	1	4	5	5	5	3	1	31	118	400	1.00
Presence of Bikeway	1	5	5	5	5	4	4	31	81	433	0.97
Surface Type	1	4	5	5	5	3	6	43	123	378	0.91
Signalized Intersections	1	4	5	5	5	3	8	40	115	387	0.91
Street Lighting	1	4	5	5	5	4	5	31	149	364	0.90
Urban Drainage	1	4	5	5	5	5	8	28	116	396	0.89
Connectivity	1	4	5	5	5	4	14	41	150	344	0.82
Obstacle-free Route	1	4	5	5	5	3	19	50	129	352	0.81
Bikeway Continuity	1	4	5	5	5	5	23	42	136	347	0.76
Horizontal Signage	1	4	5	5	5	2	23	69	159	300	0.76
Physical Barrier	1	4	5	5	5	6	29	60	138	320	0.68
Lane Width	1	4	5	5	5	8	23	70	141	311	0.66
Vertical Signage	1	4	4	5	5	4	43	84	162	260	0.61
Transit Access	1	4	5	5	5	11	31	70	157	284	0.59
Designated Parking Space	1	3	4	5	5	15	50	76	163	249	0.48
Number of Traffic Lanes	1	3	4	5	5	10	66	104	175	198	0.42
Slope	1	3	4	5	5	14	82	133	149	175	0.32
Sinuosity-free Route	1	3	4	5	5	14	101	116	138	184	0.30
Mixed Land Use	1	3	4	5	5	31	69	116	174	163	0.25
Density	1	3	4	4	5	20	73	146	180	134	0.25
Shading	1	2	3	4	5	48	127	161	118	99	0.00

1: Not at all important. 2: Slightly important. 3: Moderately important. 4: Important. 5: Very important.

The presence of bikeways and designated intersection signage indicates that potential riders are particularly concerned about the risk of crashes. Yang et al. (2020) observed in American cities that most crashes involving this mode of transportation occurred at intersections and on roads without cycling infrastructure. The most important attributes can be linked not only to the importance of physical safety but also to public safety. Well-lit routes are crucial for ES riders, as well as for pedestrians (Barros et al., 2021) and cyclists (Bagno et al., 2019) in Belo Horizonte.

Meanwhile, the attributes considered less important were “Shading” (0.00), followed by “Density” (0.25), “Mixed Land Use” (0.25), “Sinuosity-free Route” (0.30), and “Slope” (0.32). These results indicate that electric propulsion can be an attractive factor for the adoption of micromobility, as it significantly reduces physical effort, considering that attributes such as “Trees/Greenery” and “Topography” are among the most important for the adoption of conventional bicycles (Bagno et al., 2019). The low level of importance of the factors “Density” and “Mixed Land Use” may be partially linked to respondents' difficulty in associating the influence of such characteristics with the effective use of micromobility, as these attributes are highly correlated with micromobility usage (Jiao and Bai, 2020).

Although it is not possible to thoroughly assess how respondents perceive each attribute, the lower relative importance of the absence of “Sinuosity-free Route” may be related to its dual aspect. On one hand, an unnecessarily curvy layout requires more attention and can make steering more difficult for less experienced cyclists, leading to crashes (BH em Ciclo, 2019). It is assumed that the same may apply to ES riders, especially considering their ability to achieve higher speeds. On the other hand, a strategically applied curvy layout can reduce the speed of microvehicles to ensure safety (ITDP, 2017).

5. CONCLUSIONS

The findings of this study reveal that the most significant factors influencing the choice of riding e-scooters (ES) are related to micromobility infrastructure within the built environment. The relative importance of each attribute, determined through the Successive Intervals Method (SIM), provides valuable insights for prioritizing actions, such as improving the quality of cycling surfaces. The design of ES, characterized by lightweight vehicles with small solid wheels, necessitates a reevaluation of technical parameters for cycling infrastructure.

For instance, pavement conditions can have varying impacts and vibrations on different types of microvehicles. The presence of imperfections such as cracks, potholes, and steps, as well as specific pavement features like interlocking paver block joints, can significantly affect the comfort and safety of ES riders. This highlights the importance of considering the unique characteristics of each micromode when designing a shared infrastructure.

Furthermore, the observed importance of elements of supporting urban infrastructure, such as street lighting and urban drainage, reaffirms the need to pursue an interdisciplinary urban planning that benefits active modes of transportation and micromobility as a whole. Lastly, it is essential to (re)orient the transformation of space in order to develop denser and more mixed urban centers that enhance the opportunities and benefits of micro where it applies.

Due to the COVID-19 pandemic, the survey was limited to an online format. For future studies, it is recommended to include in-person surveys to capture the perspectives of a more diverse group and provide immediate assistance to respondents in case of any doubts during the questionnaire. Additionally, the filtering of respondents based on their commuting patterns in Belo Horizonte (regardless of their residency) made it challenging to establish a probabilistic sample.

It is suggested to refine respondent selection by considering their perception of circulation space quality and attribute importance in a more homogeneous study area, specific routes (e.g., residence-work, parking-work, work-related trips), or cycling corridors. A more detailed analysis of spatial specificities can offer additional insights into the perception of local attributes, such as neighborhoods, beyond the exploratory findings presented in this paper. Furthermore, as research on micromobility, particularly electric scooters, advances, adopting different criteria for grouping indicators and paying closer attention to micromode specificities may be warranted.

REFERENCES

Aasebo, H.K.W. (2019) *Shared Micro Mobility: What is Happening in our Streets?* Master's thesis. Faculty of Mathematics and Natural Sciences, University of Oslo. Oslo. Available at: <https://www.duo.uio.no/bitstream/handle/10852/69645/7/AaseboHaakon.pdf> (accessed 04/26/2021).

Bagno, P.; L.D.A.P. Almeida; L. Cardoso et al. (2019) A ciclabilidade sob a ótica de ciclistas: proposta metodológica para elaboração de um índice para Belo Horizonte. In *Congresso Brasileiro de Mobilidade Urbana – ARENA ANTP*. São Paulo: ANTP.

Bannister, D. (2007) The sustainable mobility paradigm, *Transport Policy*, v. 15, n. 2, p. 73-80. DOI: 10.1016/j.tranpol.2007.10.005.

Barros, R.M.; L.T.A. Souza; V.C.O. Couto et al. (2021) Avaliação de indicadores de caminhabilidade a partir da perspectiva de pedestres: um estudo para Belo Horizonte. In *IX Congresso Luso Brasileiro para o Planejamento, Urbano, Regional, Integrado e Sustentável*. Bauru: UNESP/FAAC, p. 1070.

Belo Horizonte (2021) Consulta Pública Nº 004/2021 – Minuta do Decreto: Regulamenta os Sistemas de Compartilhamento de Equipamentos destinados à Mobilidade Ativa e Micromobilidade, por meio de Autorização, no âmbito do Município de Belo Horizonte e dá outras providências. *Prefeitura de Belo Horizonte*, Belo Horizonte.

BH em Ciclo (2019) *Relatório Analítico do Índice de Desenvolvimento da Estrutura Cicloviária IDECiclo – Belo Horizonte, 2018/2019.* Associação dos Ciclistas Urbanos de Belo Horizonte. Available at: <https://bhemciclo.org/ideciclo-bh/> (accessed 04/26/2021).

Bruxelles. (2019) *Bruxelles Mobilité Enquête sur l'usage des Trottinettes Électriques à Bruxelles.* Bruxelles, Belgique: SPRB.

Cardoso, L. (2007) *Transporte Público, Acessibilidade Urbana e Desigualdades Socioespaciais na Região Metropolitana de Belo Horizonte.* Doctoral Thesis. Instituto de Geociências, Universidade Federal de Minas Gerais. Belo Horizonte. Available at: <http://hdl.handle.net/1843/MPBB-7A2N6A> (accessed 04/26/2021).

Carvalho, I.R.V. (2018) *Caminhabilidade como Instrumento de Mobilidade Urbana: Um Estudo de Caso em Belo Horizonte.* Master's Thesis. Escola de Engenharia, Universidade Federal de Minas Gerais. Belo Horizonte. Available at: <http://hdl.handle.net/1843/RAOA-BAPPDF> (accessed 04/26/2021).

Cervero, R. and K. Kockelman (1997) Travel demand and the 3Ds: density, diversity, and design, *Transportation Research Part D, Transport and Environment*, v. 2, n. 3, p. 199-219. DOI: 10.1016/S1361-9209(97)00009-6.

CETIC (2018) *TIC Domicílios 2018: Pesquisa Sobre o Uso das Tecnologias de Informação e Comunicação nos Domicílios Brasileiros*. São Paulo: CETIC. Available at: <https://www.cetic.br/pesquisa/domicilios/publicacoes> (accessed 04/26/2021).

Diniz, L.L.E. (2017) *Priorização das Características de Qualidade do Transporte Público por Ônibus sob a Ótica dos Usuários do Transporte Individual Motorizado: Aplicação do Método QFD.* Master's thesis. Escola de Engenharia, Universidade Federal de Minas Gerais. Belo Horizonte. Available at: <http://hdl.handle.net/1843/BUOS-ASAHAX> (accessed 04/26/2021).

Ewing, R. and R. Cervero (2010) Travel and the built environment: a meta-analysis, *Journal of the American Planning Association*, v. 76, n. 3, p. 265-94. DOI: 10.1080/01944361003766766.

Ferreira, R. G.; L. Cardoso; A. A. Souza et al. (2017) Avaliação do nível de satisfação dos usuários de um sistema de informações sobre tráfego e transportes: o caso do Portal BHTRANS. *Revista dos Transportes Públicos - ANTP*, v. 39, p. 29-48.

Fitt, H. and A. Curl (2019) *E-scooter Use in New Zealand: Insights Around Some Frequently Asked Questions*. Christchurch: University of Canterburry. DOI: 10.13140/RG.2.2.13510.93761.

Guilford, J.P. (1975) *Psychometric Methods.* (2nd ed.). London: Mc-Graw Hill PublishingCo.

Handy, S.L.; M.G. Boarnet; R. Ewing et al. (2002) How the built environment affects physical activity: views from urban planning, *American Journal of Preventive Medicine*, v. 23, n. 2, p. 64-73. DOI: /10.1016/S0749-3797(02)00475-0. PMid:12133739.

Heinen, E.; K. Maat and B. Van Wee (2011) 'The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances', *Transportation Research Part D, Transport and Environment*, v. 16, n. 2, p. 102-9. DOI: 10.1016/j.trd.2010.08.010.

Herrman, M. (2019) *A Comprehensive Guide to Electric Scooter Regulation Practice*. Master's thesis. Departamento de Paisagismo, Arquitetura e Planejamento Urbano, Universidade do Estado de Kansas, Manhattan. Available at: <http://hdl.handle.net/2097/39655> (accessed 04/26/2021).

Hollingsworth, J.; B. Copeland and J.X. Johnson (2019) Are e-scooters polluters? The environmental impacts of shared dockless electric scooters, *Environmental Research Letters*, v. 14, n. 8, p. 1-10. DOI: 10.1088/1748-9326/ab2da8.

Hora, H.R.M.; G.T.R. Monteiro and J. Arica (2010) 'Confiabilidade em questionários para qualidade: Um estudo com Coeficiente Alfa de Cronbach', *Produto & Produção*, v. 11, n. 2, p. 85-103. DOI: 10.22456/1983-8026.9321.

ITDP (2017) *Guia de Planejamento Cicloinclusivo.* Available at: <https://itdpbrasil.org/guia-cicloinclusivo/ > (accessed 04/26/2021).

Jacobs, J. (2011) *Morte e Vida de Grandes Cidades* (3. ed.). São Paulo: WMF Martins Fontes.

Januzzi, P.M. (2002) *Indicadores Sociais na Formulação e Avaliação de Políticas Públicas.* p. 1-9. Available at: < https://www.nescon.medicina.ufmg.br/biblioteca/registro/Indicadores_sociais_na_formulacao_e_avaliacao_de_politicas_publicas/62> (acessed: 04/26/2021).

Jiao, J. and S. Bai (2020) Understanding the shared e-scooter travels in Austin, TX, *ISPRS International Journal of Geo-Information*, v. 9, n. 2, p. 135. DOI: 10.3390/ijgi9020135.

Lucchesi, S.T.; R.R. Candido; S.P. Schwabe et al. (2019) A mobilidade urbana brasileira inclui ações em prol da smart mobility em seu planejamento? Uma avaliação qualitativa dos termos de smart mobility nos planos de mobilidade. In *XXXIII Congresso de Pesquisa e Ensino em Transportes da ANPET*. Balneário: ANPET, p. 449-460.

Lyons, G. (2018) Getting smart about urban mobility: aligning the paradigms of smart and sustainable, *Transportation Research Part A, Policy and Practice*, v. 115, p. 4-14. DOI: 10.1016/j.tra.2016.12.001.

Matthew, J.K.; M. Liu; S. Seeder et al. (2019) Analysis of E-Scooter trips and their temporal usage patterns. *ITE Journal*, v. 89, n. 6, p. 44-9.

McKenzie, G. (2019) Urban mobility in the sharing economy: a spatiotemporal comparison of shared mobility services, *Computers, Environment and Urban Systems*, v. 79, p. 101418. DOI: 10.1016/j.compenvurbsys.2019.101418.

NACTO (2020) *NACTO: City Transportation Action Update*. Available at: <https://docs.google.com/spreadsheets/d/1xBf6gMAwNSzNTr0-CbK_uTA0ZapWGiOP58Dfn6qeC6Y/edit#gid=1511672872> (accessed 04/26/2021).

Orr, B.; J. MacArthur and J. Dill (2019) *The Portland E-Scooter Experience*. Available at: <https://pdxscholar.library.pdx.edu/trec_seminar/163> (accessed 04/26/2021).

Platt, L. and G. Rybarczyk (2021) Skateboarder and scooter-rider perceptions of the urban environment: a qualitative analysis of user-generated content, *Urban Geography*, v. 42, n. 10, p. 1525-51. DOI: 10.1080/02723638.2020.1811554.

Providelo, J.K. and S.P. Sanches (2011) Roadway and traffic characteristics for bicycling, *Transportation*, v. 38, n. 5, p. 2011.

Queiroz, C.S. (2020) 'Patinetes elétricos e o direito urbanístico: o uso dos patinetes elétricos como instrumento de mobilidade urbana', *Revista de Educação do Vale do Arinos*, v. 7, n. 1, p. 29-49.

Reck, D.J.; S. Guidon and K.W. Axhausen (2020) Modelling shared e-scooters in Louisville, Kentucky: a spatial regression approach. In *XCIX Annual Meeting of the Transportation Research Board: New Mobility and Transportation Technology Takeaways (TRB 2020).* Washington: IVT, ETH Zurich.. DOI: 10.3929/ethz-b-000371224

Rio de Janeiro (2019) Decreto nº 46.181, de 2 de julho de 2019. Disciplina a utilização da infraestrutura de mobilidade urbana no Município por meio da exploração econômica do compartilhamento de patinetes elétricos, em caráter experimental, e dá outras providências. *Diário Oficial do Rio de Janeiro*, Rio de Janeiro.

São Paulo. (2019) Decreto nº 58.906, de 9 de agosto de 2019. Regulamenta os serviços de compartilhamento de patinetes elétricas acionadas por meio de plataformas digitais. *Diário Oficial de São Paulo*, Ano 64, nº 149, São Paulo.

Segnestam, L. (2002) *Indicators of Environmental and Sustainable Development: Theories and Practical Experience*s. Washington, DC: World Bank.

Shaheen, S.A.; S. Guzman and H. Zhang (2010) Bikesharing in Europe, the Americas, and Asia: past, present, and future, *Transportation Research Record: Journal of the Transportation Research Board*, v. 2143, n. 1, p. 159-67. DOI: 10.3141/2143-20.

St-Louis, E.; K. Manaugh; D. Van Lierop et al. (2014) The happy commuter: a comparison of commuter satisfaction across modes, *Transportation Research Part F: Traffic Psychology and Behaviour*, v. 26, p. 160-70. DOI: 10.1016/j.trf.2014.07.004.

Viola, P.D.D. (2017) *Potencial de Viagens por Bicicletas em Belo Horizonte em Belo Horizonte: Um Estudo Exploratório da Pesquisa Origem e Destino de 2012.* Master's Thesis. Escola de Engenharia, Universidade Federal de Minas Gerais, Belo Horizonte. DOI: 10.34096/rtt.i20.6397

Yang, H.; Q. Ma; Z. Wang et al. (2020) Safety of micro-mobility: analysis of E-Scooter crashes by mining news reports, *Accident; Analysis and Prevention*, v. 143, p. 105608. DOI: 10.1016/j.aap.2020.105608. PMid:32480017.