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Development of a walkability index from the 15-minute city perspective

Desenvolvimento de um índice de caminhabilidade sob a perspectiva da cidade de 15 minutos

Desarrollo de un índice de caminabilidad desde una perspectiva de ciudad de 15 minutos

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RESUMO
O planejamento urbano centrado no pedestre vem ganhando notoriedade por parte de estudiosos e formuladores de políticas públicas imersos no debate sobre sustentabilidade e saúde. Para avaliar o quão convidativo é o espaço urbano para os pedestres, geralmente utiliza-se um índice de caminhabilidade. Os primeiros índices surgiram na década de 90, porém, atualmente não há um consenso sobre qual seria a ferramenta mais precisa ou mais indicada para avaliar cada cenário, o que implica no contínuo surgimento de novas metodologias. Dessa forma, o presente artigo busca contribuir com o avanço da literatura através do desenvolvimento de um índice de caminhabilidade sob a perspectiva da cidade de 15 minutos. Com esse intuito, foi realizada uma revisão da literatura sobre índices de caminhabilidade, para melhor embasar a construção da ferramenta. Posteriormente, é estruturado o índice de caminhabilidade, com 30 indicadores divididos em 5 categorias: infraestrutura pedonal, estética e conforto, diversidade (cidade de 15 minutos), segurança e mobilidade. A presente pesquisa é de importante relevância social, onde resultados obtidos podem representar uma grande contribuição para os pesquisadores da área, gestores urbanos e para a sociedade em geral, uma vez que um diagnóstico da caminhabilidade preciso é o primeiro passo para a condução de melhorias mais assertivas da infraestrutura pedonal.

PALAVRAS-CHAVE: Planejamento urbano. Cidade de 15 minutos. Transporte ativo. Infraestrutura pedonal.

SUMMARY
Pedestrian-centered urban planning has been gaining notoriety among researchers and public policy makers immersed in the debate on sustainability and health. To assess how inviting an urban space is to pedestrians, a walkability index is generally used. The first indices appeared in the 90s, however, there is currently no consensus on which would be the most accurate or best tool to evaluate each scenario, which implies the continuous emergence of new methodologies. Therefore, this article aims to contribute to the advancement of literature through the development of a walkability index from the perspective of the 15-minute city. For this purpose, a review of the literature on walkability indices was carried out, to better support the construction of the tool. Subsequently, the walkability index is structured, with 30 indicators divided into 5 categories: pedestrian infrastructure, aesthetics and comfort, diversity (15-minute city), safety and mobility. This research is of important social relevance, where results obtained can represent a great contribution to researchers in the area, urban managers and society in general, since an accurate diagnosis of walkability is the first step towards conducting more assertive improvements to pedestrian infrastructure.

KEYWORDS: Urban planning. 15 minutes city. Active transport. Pedestrian infrastructure.

RESUMEN
La planificación urbana centrada en el peatón ha ido ganando notoriedad entre académicos y formuladores de políticas públicas inmersos en el debate sobre sostenibilidad y salud. Para evaluar qué tan atractivo es un espacio urbano para los peatones, generalmente se utiliza un índice de caminabilidad. Los primeros índices aparecieron en los años 90, sin embargo, actualmente no existe consenso sobre cuál sería la mejor o más precisa herramienta para evaluar cada escenario, lo que implica el continuo surgimiento de nuevas metodologías. Por lo tanto, este artículo busca contribuir al avance de la literatura a través del desarrollo de un índice de caminabilidad desde la perspectiva de la ciudad de 15 minutos. Para ello se realizó una revisión de la literatura sobre índices de caminabilidad, para sustentar mejor la construcción de la herramienta. Posteriormente, se estructura el índice de caminabilidad, con 30 indicadores divididos en 5 categorías: infraestructura peatonal, estética y confort, diversidad (ciudad en 15 minutos), seguridad y movilidad. Esta investigación es de importante relevancia social, donde los resultados obtenidos pueden representar un gran aporte para los investigadores del área, los gestores urbanos y la sociedad en general, ya que un diagnóstico certero de la caminabilidad es el primer paso para realizar mejoras más asertivas en la infraestructura peatonal.

PALABRAS CLAVE: Planificación urbana. 15 minutos ciudad. Transporte activo. Infraestructura peatonal.

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1 INTRODUCTION

Pedestrian-centered urban planning has been gaining notoriety among scholars and public policy makers immersed in the debate on sustainability and health (Domènech-Abella *et al.*, 2020; Wasfi *et al.,* 2016a; Zapata-Diomedi; Veerman, 2016). Given this context, the concept of walkability gained a prominent role and began to be seen as a viable solution to shape the urban environment and transform cities into livelier, safer, sustainable and healthier spaces (Gehl, 2013).

Walkability can be defined as a measure that helps assess the quality of urban space dedicated to pedestrians (Wang; Yang, 2019). An area considered walkable has certain common characteristics, such as: sidewalks with appropriate width and paving, public and road safety, diversity of land uses, protection against rain and excess heat and good lighting (Mobilize, 2019); and consequently, results in an environment capable of promoting active transport and physical activity, which are considered healthier lifestyle behaviors (Rebecchi *et al.,* 2019).

Since its first appearances, in the early 90s, it is possible to observe that among the definitions of walkability, they all converge both on the importance of the qualitative aspects of urban space, as well as on the relevance attributed to physical space (Albala, 2022). Therefore, several attributes must be considered to evaluate how inviting the urban space is for pedestrians, and for this, a walkability index is generally used.

Bradshaw (1993) was probably the first to develop a methodology to measure walkability, motivated by the need to estimate property values in Canada based on neighborhood characteristics. Since then, many indices have been developed by different researchers and for different purposes. The exploration of the concept of walkability resulted in an increase in the number of variables that make up this measure and, in their definitions, when creating the indices. The final grade is generally obtained in two ways: by an arithmetic sum, based on a combination of the variables adopted, or the values are classified into deciles or quintiles (Khanal; Mateo-Babiano, 2016; Shashank; Schuurman, 2019).

A tool that is widespread and accepted by the scientific community is the *Walk Score,* which analyzes the walkability of neighborhoods based on the distance and ease of access to thirteen amenities, such as: pharmacies, schools, parks and stores (Wasfi *et al.*, 2016b), and therefore, presents the limitation of not considering other urban aspects, such as pedestrian safety and the condition of sidewalks. In research where a walkability index for women, the *Women's Walkability Index* (WWI), was created and compared with the *Walk Score,* it was noted that participants classified crime, the presence of homeless people and the cleanliness of streets and sidewalks, as the three most influential factors in women's walkability. Some less walkable areas according to WWI due to the high density of crime and homelessness, have almost the maximum score when evaluated by *Walk Score* (Golan *et al.*, 2019).

The different scores obtained between the *Walk Score* and the WWI reflect a common limitation among different existing walkability indices, especially methodologies focused on objective analyses. The walkability of an area is perceived differently by each pedestrian. Therefore, an adult woman may consider the walkability of a certain location acceptable when walking

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alone, however, another woman of the same age group pushing a baby stroller, or a wheelchair user may come across obstacles along the route and evaluate the same location as being insufficient for walking. Therefore, walkability indices need to include indicators that are sensitive to the peculiarities of different groups of pedestrians.

On the other hand, it is essential to highlight that certain trips are not viable for walking. Although good walkability favors and encourages this means of transport, for longer distances it may be necessary to resort to other modes. For this reason, good walkability should not only refer to the physical quality of the tours, but also the possibility of carrying out daily activities at walkable distances, as outlined in the "15-minute city" concept.

The "15-minute city" is a concept created by author Carlos Moreno in 2016, who argues that an adequate urban configuration should provide local inhabitants with the possibility of accessing all basic services at distances of no less than 15 minutes on foot or by bike. According to Moreno *et al.* (2021), such a configuration should allow residents to effectively fulfill six urban social functions, which would be (a) decent housing, (b) job opportunities, (c) access to commerce of essential items, (d) access to health, (e) access to education and (f) access to leisure and entertainment options (Eleutério; Santos; Silva, 2022).

The idea of the "15-minute city" gained greater visibility a few years after its creation, during the coronavirus pandemic, in the capital of France. Due to travel restrictions, the model proposed by Moreno saw the possibility of rethinking the city's mobility by investing in walking and cycling and seeking the way back to a city on a human scale. Whether living in the city center or in any other neighborhood, the ideal 15-minute city should provide resources so that its residents can enjoy essential amenities through active mobility.

After years of shaping public spaces according to the guidelines of modernist urban planning, marked by the prioritization of motorized vehicles and the zoning of municipalities, with separation between residences, jobs and leisure areas, the search for solutions to urban mobility problems It is today a central theme for those responsible for city management and planning (Silva, A.; Silva, B., 2023). Given this scenario, walkability is seen as a means not only to improve urban mobility, but also to alleviate other problems triggered by excessive car use, such as noise and air pollution generated by traffic, the incidence of diseases caused by sedentary lifestyle and the absence of urban vitality. And for this, it is essential that there is progress in methodologies for assessing walkability, and that they are easy to understand and apply.

Therefore, this article aims to develop a walkability index aimed at the 15-minute city perspective. Studies of this nature can help cities obtain better diagnoses of their pedestrian infrastructure, orient themselves more precisely and invest in walkability during their growth, leading managers to make effective decisions, preventing them from becoming chaotic metropolitan spaces, where solutions or adaptations are much more complicated and costly to implement later.

2 THEORETICAL FRAMEWORKS

Attempts to quantify walkability began in the 1990s and it is believed that Chris Bradshaw (1993) was the first to develop an index with this objective. In 1992, in Ottawa, Canada,

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urban property owners suffered from increased taxes on properties that were based on market values. The traders began to argue that the values in question did not reflect the property owners' ability to pay taxes. Others argued that a large proportion of neighborhood residents traveled on foot, and for this reason, they made little use of the infrastructure for vehicle circulation paid for by property taxes in their neighborhoods (Ghidini, 2011).

Bradshaw (1993) then saw the possibility of quantifying walkability and using this as a metric to calculate tax values depending on their degree applied to the blocks or zones of the neighborhood. The walkability index created could also be useful for evaluating the value of properties and the urban space surrounding buildings. The methodology proposed by the author has a practical and direct application, where according to Bradshaw (1993), walkability has four basic characteristics:

> 1) A pleasant microenvironment for pedestrians: wide and level sidewalks, small intersections, narrow car lanes, good lighting, adequate cleaning and absence of obstructions. 2) A range of useful destinations within walking distance: shops, services, jobs, offices, recreation, libraries, etc. 3) a natural environment that moderates the extremes of weather - wind, rain, sunlight - while providing the refreshment of the absence of excessive human use. It is free from excessive noise, air pollution or dirt, stains and grime from motor traffic. 4) Socially diverse local culture, as this increases contact between people and economic gains for commerce in the region (Bradshaw, 1993, p. 2, our translation).

Over the years, several methodologies to measure walkability have been developed, but to date there is no consensus on which tool would be most accurate or best suited for each scenario. Consequently, the walkability indices used vary according to the context of the study area and the objective of each research. Therefore, given the large volume of existing walkability indices, the purpose of this topic is not to address all of them exhaustively, but rather to gather, present and discuss some relevant indices in national and international literature, addressing the main peculiarities of each of them.

A total of 21 walkability assessment tools are briefly analyzed below, found from systematic reviews (Blečić *et al.*, 2020; Dragović et al., 2023; Maghelal; Capp, 2011; Shields *et al.*, 2023), search in databases or through the snowball method, summarized in Table 1. Subsequently, a discussion is made regarding the material found in the 21 methodologies.

Table 1- Summary of the analyzed walkability indices

Authors/Year	Region	Number of indicators	Collection method	Approach	Unit of analysis
Bradshaw (1993)	United States	10	Questionnaire	Subjective and Objective	Area
Ferreira; Sanchez (2001)	Brazil	5	Field collection	Subjective and Objective	Segment
Saelens *et al.,* (2003)	United States	7	Field data collection Questionnaire	Subjective	Segment or area
Cunningham *et al.*, (2005)	Canada	45	Field data collection	Objective	Segment
Ewing *et al.*, (2006)	United States	5	Theoretical work	Objective	Segment

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Clifton; Livi Smith; Rodriguez (2007)	United States	31	Field data collection Checklist	Subjective and Objective	Segment
Frank et al. (2010)	United States	4	Geographic census	Objective	Area
Carr; Dunsiger; Marcus (2011) (Walk Score)	United States	1	Digital data collection	Objective	Segment
Griew *et al.*, (2013)	United Kingdom	26	Field data collection Digital data collection Checklist	Objective	Segment or area or point
D'Alessandro *et al.*, (2015)	Italy	12	Field data collection	Subjective	Segment
Talavera; Soria-Lara (2015)	Spain	5	Public management data and field collection	Subjective and Objective	Area
Moura; Cambra; Gonçalves, (2017)	Portugal	17	Field data collection	Subjective and Objective	Segment
Sutti; Paiva (2017)	Brazil	8	Field collection	Objective	Segment
Saucer; Magagnin (2018)	Brazil	38	Field collection	Objective	Area
ITDP Brazil (2018)	Brazil	15	Field data collection	Objective	Segment
Keyvanfar *et al.*, (2018)	Malaysia	92	Theoretical work	Objective	Segment
Al Shammas; Escobar (2019)	Spain	5	GIS	Subjective and Objective	Segment
SampaPé (2019)	Brazil	23	Field data collection	Objective	Segment
Golan *et al.*, (2019)	United States	11	GIS and questionnaires	Subjective and Objective	Block
Steinmetz-Wood *et al.*, (2019)	Canada	40	Field data collection	Objective	Segment
Albala (2022)	Brazil	19	Field data collection and GIS	Objective	Area

Source: Authors, 2024.

There are numerous tools to evaluate aspects of the built environment that promote or inhibit walking. For example, the Sustainable Urban Mobility Index (IMUS) (Costa, 2008), which has the potential to diagnose and monitor a city's urban mobility; the *International Physical Activity Questionnaire index* developed to assess whether urban space favors physical activity (Craig *et al.*, 2003). However, due to the large number of tools that indirectly measure whether a given environment is walkable or not, it was decided to focus on a sample specifically focused on walkability.

The way walkability data is collected differs between authors and it is possible to find articles where data collection is done through questionnaires (Bradshaw, 1993; Saelens *et al.* , 2003), field data collection (D'Alessandro *et al.* , 2015; ITCSG, 2019; ITDP, 2018), online data collection through platforms such as *Google Street View* (Griew *et al.* , 2013; Steinmetz-Wood *et al.* , 2019) and GIS applications (Albala, 2019; 2022; Walkability data surveys carried out through analysis of street images are generally faster and require less financial and human resources. On the other hand, the collection carried out in the field captures the experience that the pedestrian has when walking through the area.

Regarding to approaches, of the 21 tools analyzed, 12 (57.2% of the sample) are objectively oriented tools, 2 (9.5%) are subjectively oriented and 7 (33.3%) use both forms of

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approach. In the sample universe of this review, a significant portion of the indices do not consider the perception of pedestrians in their data collection. The predominant unit of analysis among the indices was the sidewalk segment (13 = 61.9%), indices that used the complete area as the unit of analysis were also found (5 = 23.8%), indices that considered both the sidewalk segment as the complete area (2 = 9.5%), and only one that considered the block as the spatial unit of analysis (4.8%). Such data are summarized in Table 1.

The differences between pedestrians are not covered by most walkability assessment tools, only the IAAPE (Moura; Cambra; Gonçalves, 2017) addressed this topic, however, with some limitations. The weight that each indicator presents for each type of pedestrian was determined from a panel carried out with just 17 pedestrians. Furthermore, the authors did not consider differences between men and women. In a literature review of parameter-based models for walkability assessment Dragović *et al.*, (2023) highlighted the need to develop a method for assessing the built environment for people with disabilities, since there is little evidence of such tools.

were listed by Dragović *et al.*, (2023), however, it is possible to observe redundancies in some variables, such as the terms "public spaces" and "open public spaces" or "sidewalk conditions" and "pedestrian path conditions". Although the terms are different, in practice the authors are measuring the same variable. Therefore, considering all 193 variables when creating a walkability index would be overlapping information, measuring and counting the same indicator more than once.

The weight that each variable has in the final grade is also not something unified among the walkability indices. Among the 21 methodologies analyzed, 57.1% (n = 12) did not consider the indicators and each of them is given the same importance in the final grade. In the other indices there were weights calculated following different criteria. Frank *et al.,* (2010) considered that the intersection density variable was the most relevant in the index and therefore would have twice the weight of the other variables. Pires and Magagnin, 2018 and D'Alessandro *et al.*, (2015) held panels with urban planning experts to build a weighting system for the indicators of their tools. Other authors weighed their variables depending on the perception of pedestrians, through interviews or questionnaires, they determined which indicators most influenced or inhibited walking (Ferreira; Sanches, 2001; Moura; Cambra; Gonçalves, 2017; Talavera; Soria-Lara, 2015).

In general, nine categories or domains of items were observed to measure walkability, distributed according to the type of indicator. The categories identified in the 21 tools covered are: public and road safety, comfort, aesthetics/attraction, pedestrian infrastructure, cycling infrastructure, mobility, destination availability, road attributes and environment. Not all walkability indices address all the categories, and some tools do not subdivide their indicators into categories (Al Shammas; Escobar, 2019; Bradshaw 1993; Frank *et al.*, 2010; Saelens *et al.*, 2003).

The categories are like those cited in the study by Blečić *et al.*, (2020), a guide for authors to build tools to evaluate walkability, where the authors grouped the indicators found in the literature into four categories: attractiveness, efficiency and comfort, safety and protection and amenities/pleasantness. Dragović *et al.*, (2023) identified seven groups, which are: functionality, safety, comfort, mobility, environment, connectivity and aesthetics.

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The number of indicators that each walkability index groups together is inconsistent. In the 21 tools analyzed, it is possible to find indexes made up of 4 (Frank *et al.* , 2010) or 5 indicators (Al Shammas; Escobar, 2019; Ewing *et al.,* 2006; Ferreira; Sanches, 2001; Talavera; Soria-Lara, 2015) to indices constructed with more than 90 variables (Keyvanfar *et al.,* 2018), with 17 being the average of the indicators of the 21 indices and 12 being the median. The most cited urban indicators among the authors were: diversity of land use (n = 12), presence of trees and/or proximity to green areas (n = 12), width of sidewalks (n = 11), sidewalk coating (n = 9) and lighting (n = 9).

Other indicators commonly cited in the walkability indices analyzed were: crossings (n = 7), street connectivity (n = 7), signage (n = 7), traffic control devices (n = 6), continuity of sidewalks (n = 6), unevenness (n = 6). On the other hand, many indicators were only mentioned in one of the indexes, such as: representativeness and targeted information, possibility of conflict between vehicle and pedestrian, waiting space for pedestrians on the corner, lack of housing and accident rate.

The indicator scoring scale has a direct influence on the efficiency that the walkability index will have when evaluating a given location. When you choose to dichotomize the variables, your scores will have only two results, with no middle terms. For example, a court face size variable being dichotomous, where 0 would be assigned to segments with more than 200 meters in length, considered insufficient, and 1 would be assigned to segments with less than 200 meters in length, considered sufficient, a segment with 201 meters it would be considered insufficient, just like a 1000 meter segment, for very little a terrible scenario would be equated with a scenario close to sufficient.

It is possible to identify such a limitation in some of the 21 indices analyzed, an example is the iCam 2.0 of ITDP Brasil, where the variable scoring scale varies between 0 and 3. In the lighting indicator, to receive the minimum score and be considered sufficient, the The evaluated segment must have lighting points facing the street and lighting points at both ends. Therefore, a segment that has lighting points along its length and at one of its ends is considered insufficient, just like a completely dark segment. Therefore, it is noted that the more fractional the scoring scale, the more detailed and precise the scenario analysis will be.

Finally, it is observable that walkability indices are possibly oriented towards the reality of a city or in relation to a specific context, as they are generally developed based on urban, cultural and socioeconomic characteristics specific to the location where they are applied. Certain indices do not have adjustment or calibration mechanisms that allow their direct reapplication in other locations, thus requiring adaptations considering urban infrastructure, mobility culture, climate, security and public policies.

3 METHODOLOGY

Many studies that sought to evaluate walkability report the difficulty of identifying all variables in the field, which makes the construction and application of indices difficult and subjective (Krambeck, 2006). For this reason, a bibliographical review was carried out substantiated in the previous topic, which sought to establish in the literature the theoretical basis necessary

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to structure the present walkability index and obtain a methodology compatible with the objectives of this article.

30 indicators were selected to compose the walkability index from the perspective of the 15-minute city, where the tool's unit of analysis will mainly be the sidewalk segment. The variables were gathered with a view to reapplication of the index; therefore, indicators were chosen whose information was easy to obtain, through on-site visits, data from Municipal management and Google Maps.

Based on the findings in the literature, the 30 indicators were grouped into 5 categories (also called domains by some authors). The defined categories are not mutually exclusive, as they bring together distinct but complementary attributes that contribute to the assessment of pedestrian accessibility.

The walkability index indicators will be evaluated on a scoring scale that varies between 0 and 1, with 5 possible scenarios: excellent (1.00), good (0.75), regular (0.50), bad (0, 25) and terrible or non-existent (0.00), to detail as much as possible each context analyzed. The following topic presents the results, with the definitions and scoring scales for each indicator. In the complementary material, the index is presented in full, with details about the assessment location, how to carry out the measurement and references for each indicator.

4 RESULTS

The index was created with the aim of evaluating walkability from the perspective of the 15-minute city, and to this end, the tool was structured with 30 indicators grouped into 5 categories.

Initially, an extensive literature analysis was carried out seeking to gather the necessary indicators to characterize a walkable urban space from the perspective of the 15-minute city concept, to later determine the most coherent way to group them into categories, and finally, obtain the walkability index. There is no consensus among authors on what is the most appropriate way to group urban indicators, nor on how many dimensions the variables that assess walkability can be divided into. The General Theory of Walkability, created by Speck (2013), explains that the urban environment needs to offer means for walking to be safe, interesting, comfortable and beneficial. Dragović *et al.* (2023), in a review of walkability indices, surveyed 191 urban indicators and concluded that they can be grouped into seven dimensions: (1) functionality; (2) aesthetics; (3) accessibility; (4) mobility; (5) connectivity; (6) comfort and (7) safety. Blečić *et al.*, (2020), in turn, when proposing a guide for urban analysts to evaluate walkability, considers the following dimensions: (1) efficiency and comfort; (2) safety, security and trust; (3) amenities and (4) attractiveness. In this index, the indicators found in the literature were grouped into five categories: (1) pedestrian infrastructure; (2) security; (3) mobility; (4) aesthetics and comfort and (5) 15-minute city, as it is believed that these five dimensions can summarize the urban aspects that most influence the characterization of a walkable area aimed at the conception of a 15-minute city. Below are the definitions of each category.

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• **Pedestrian infrastructure:** deals with physical aspects of the sidewalk necessary for the user to move around comfortably and safely, such as dimensions, materials used in the covering, accessibility elements.

• **Aesthetics and comfort:** covers indicators that, when considered, encourage pedestrians to spend time in urban spaces, as they make walking attractive, pleasant and comfortable. It also includes the "living facades" indicator, which in addition to being pleasant, contributes to the walker's feeling of security.

• **Diversity (15-minute city):** the indicators aim to identify whether, within the analyzed area, residents can effectively fulfill six basic social functions (a) decent housing, (b) job opportunities, (c) access to commerce of essential items, (d) access to healthcare, (e) access to education and (f) access to leisure and entertainment options. To offer quality of life to its residents and cover the six urban social functions mentioned above in a walk of up to 15 minutes, the urban area analyzed must present four fundamental principles: density, proximity, diversity and digitalization.

• **Safety:** the category brings together indicators that deal with the safety and integrity of walkers in general, addressing variables that protect pedestrians against traffic risks and indicators that contribute to the individual's feeling of public safety.

• **Mobility:** the category addresses indicators that influence pedestrian flow and the viability of walking as a means of transport. The urban design and permeability of the area are analyzed through the "connectivity" indicator and the integration of active mobility with other modes makes up the second indicator of the category.

Next, the selected indicators are presented, separated by categories, with a brief description and scoring scales, in Tables 2 to 6.

4.1 Category: pedestrian infrastructure

Table 2- Indicators for the Pedestrian Infrastructure category

FREE BAND WIDTH
DEFINITION - The indicator refers to a free lane or sidewalk intended exclusively for pedestrian circulation. Considered as the distance between the access lane to the lots and the service lane. It must be free from temporary or permanent obstacles and must meet the flow of people in that location.
SCORING SCALES - FL < 0.55 m - **Poor/nonexistent /** 0.55 m <= FL < 1.20 m – **Bad /** 1.20 m <= FL < 1.80 m – **Regular /** 1.80 m < = FL < 2.40 m – **Good /** > 2.40 m – **Excellent**
SIDEWALK COATING
DEFINITION - Sidewalk coating analyzes the surface materials used in the construction of the sidewalk and their influence on pedestrian comfort and safety. The absence of coating or the use of inappropriate paving materials can cause accidents, discomfort and compromise the mobility of certain groups of people, such as the elderly, children, people with disabilities or women using baby strollers.
SCORING SCALES - Section without sidewalk – **Terrible/non-existent /** The sidewalk is not covered or uses inappropriate materials for more than 50% of its length – **Bad /** The sidewalk is covered and uses suitable materials for at least 75% of its length – **Regular /** The sidewalk has a coating and uses suitable materials for at least 90% of its length – **Good /** The sidewalk has, throughout its entire length, a regular, firm, stable surface, not shaking for wheeled devices and non-slip, under any condition (dry or wet) - **Great**
LONGITUDINAL INCLINE
DEFINITION - The indicator refers to the longitudinal slope in the sidewalk segment, ideally less than 5%.
SCORING SCALES - The sidewalk segment has a slope of up to 1% and follows the slope of the road continuously – **Excellent /** The sidewalk segment has a slope between 1% and 3% - **Good /** The sidewalk segment has a slope between 3% and 5% but has a level resting area every 50 m – **Fair /** The sidewalk segment has a slope between 3%

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and 5% and does not have a level resting area every 50 m – **Bad /** The sidewalk segment has a slope greater than 5% - **Terrible**
CROSS SLOPE
DEFINITION - The transverse slope refers to the slope between the face of the lot and the curb, necessary for rainwater drainage to occur, however, on external floors it should not be greater than 3%.
SCORING SCALES - All lots on the side of the block have a transverse slope (TI) between 1 and 3% – **Excellent /** 90% of lots on the side of the block have IT between 1 and 3% - **Good /** 75% of lots on the side of the block block have IT between 1 and 3% - **Fair /** 50% of the lots on the block face have IT between 1 and 3% - **Bad /** IT greater than 3% across the entire length of the block face - **Terrible**
HOLES AND DIFFERENCES
DEFINITION - The indicator analyzes the occurrence of irregularities on sidewalks caused by holes or unevenness. These defects can cause discomfort and accidents for pedestrians, in addition to restricting the movement of the elderly, children and people with disabilities.
SCORING SCALES - There are no holes or unevenness throughout the evaluated segment – **Excellent /** There are between 1 and 3 holes or unevenness in the evaluated segment – **Good /** There are between 3 and 5 holes or unevenness in the evaluated segment – **Fair /** There are between 5 and 7 holes or unevenness in the evaluated segment – **Bad /** There are more than 7 holes or unevenness in the evaluated segment - **Poor**
VEHICLE OCCUPANCY
DEFINITION - The occupation of sidewalks by vehicles is a common practice where users of private transport use the front setbacks of facades as parking, compromising the free lane necessary for the flow of pedestrians in the area. In addition to taking up sidewalk space and compromising pedestrian safety, the occupation of the sidewalk by vehicles can block the visual connection between the sidewalk and the interior of buildings, creating insecurity for walkers.
SCORING SCALES - No section of sidewalk is used as vehicle parking – **Excellent /** 90% of the segment is used as vehicle parking – **Good /** 75% of the segment is used as vehicle parking – **Fair /** 50% of the segment is used as vehicle parking or the entire sidewalk segment is used as vehicle parking, but there is a free lane of at least 1.20 m for pedestrians to move around – **Bad /** The entire sidewalk segment is used as vehicle parking and there is no safe space for pedestrians to move around - **Terrible**
ACCESSIBILITY ELEMENTS
DEFINITION - The indicator analyzes whether the sidewalk has accessibility elements necessary to make the flow comfortable and safe for people with reduced mobility. The occurrence of accessibility ramps, when necessary, with a slope of less than or equal to 8.33% is analyzed; the existence of tactile and directional flooring, audible traffic lights, among other elements.
SCORING SCALES - There is directional and warning flooring throughout the entire stretch (for furniture and at crossings), at crossings the sidewalks are at the same level as the road or there are accessible ramps, there are audible traffic lights – **Excellent /** 90% of the stretch has directional flooring and warning (for furniture and at crossings), at all crossings the sidewalks are at the same level as the road or there are accessible ramps, there is an audible traffic light – **Good /** 75% of the section has a directional and warning floor (for furniture and at crossings), at all crossings the sidewalks are at the same level as the road or there are accessible ramps, there is no audible traffic light – **Regular /** Only 50% of the section has a directional and warning floor (for furniture and at crossings), half of the crossings are sidewalks they are not on the same level as the track or there are no accessible ramps, there is no audible traffic light – **Bad /** There is no element of universal accessibility in the analyzed section - **Very Bad**
CONTINUITY OF THE SIDEWALK/ROUTE
DEFINITION - Continuity evaluates the possibility of walking around the city in the form of a network, without interruptions. Continuity of the route can be ensured through good sidewalk conditions throughout the analyzed area and safe crossings between blocks.
SCORING SCALES - The free lane is linear throughout the entire stretch and when there is a crossing, it is at level (or there is an accessible ramp) and in continuity with the free lane on the sidewalk – **Excellent /** The free lane has some deviations and/or the crossings are located in the continuity of the free lane, but are at level or are accessible – **Good /** The free lane has some deviations and/or the crossings are located in the continuity of the free lane, but are not at level or are not accessible – **Fair /** The free lane there are interruptions and/or the crossing is displaced from the free lane on the sidewalk - up to a maximum of 2 meters from the lot line - and they are not level or are not accessible – **Bad /** There is no linearity in the free lane (or there is no free lane) and/or crossings are more than 2 meters offset (from the lot line to the crossing), and are not level or accessible - **Terrible**

Source: Authors, 2024.

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4.2 Category: aesthetics and comfort

Table 3- Indicators for the Aesthetics and Comfort category

LIVING FACADES
DEFINITION - The indicator evaluates the number of openings present on the ground floor facades of buildings that allow people inside to assume the role of "eyes on the street", contributing to the pedestrian's feeling of safety. Facades with commercial points, access openings to the building and transparent windows are attributes that make the facade "alive".
SCORING SCALES - All lots in the segment have facades that enable a visual connection between the interior and exterior of the buildings or have 3 or more commercial points - **Excellent /** 15% of the segment has blind facades and there are at least two facades with openings to the public or commercial points – **Good /** 30% of the segment is formed by blind facades and there is at least one facade with opening to the public or commercial point – **Fair /** 50% of the segment or more is formed by blind facades and there are no facades with opening to the public or with commercial points – **Bad /** The segment is entirely made up of blind facades that make it impossible to visually connect the interior of the buildings and the sidewalks, there are no facades open to the public or with commercial points – **Terrible**
SHADE AND SHELTER
DEFINITION - Refers to the existence of protection against bad weather caused by trees, awnings, awnings and even the projection of shadows from the buildings themselves located in the analyzed area.
SCORING SCALES - In 75% of the segment or more it is possible to walk under shelter from rain and sun – **Excellent /** In 50% of the segment it is possible to walk under shelter from rain and sun – **Good /** In more than 25% of the segment it is possible to walk under shelter from rain and sun – **Fair /** In less than 25% of the segment it is possible to walk under shelter from rain and sun – **Bad /** There is no structure that provides shade/shelter - **Terrible**
URBAN FURNITURE FOR REST
DEFINITION - Analyzes the existence of urban furniture that allows pedestrians to stop and rest along the route. Urban furniture, such as benches and flowerbeds, can act as spaces for support, rest and contemplation, and functions as inclusion elements for different groups of pedestrians.
SCORING SCALES - There are several options of urban furniture for resting in the evaluated segment (benches, benches in squares, parklets or others) – **Excellent /** There is only one urban furniture for resting – **Good /** There is only opportunity to rest in an improvised way – **Average /** There is street furniture for resting in the evaluated segment, but it is dirty or deteriorated – **Bad /** There is no street furniture for resting in the evaluated segment - **Terrible**
NOISE POLLUTION
DEFINITION - Analyzes the sound intensity level, at the time of data collection in the field, resulting from the combination of several sound sources, such as road traffic, commercial activities, sirens and the like. According to the WHO (1999), noise pollution acts as one of the main environmental risks to the physical and mental health of the population. High levels of urban noise can cause discomfort to pedestrians and discourage walking in the area.
SCORING SCALES - Urban noise less than 55 decibels – **Excellent /** Urban noise between 55 and 60 decibels – **Good /** Urban noise 61 and 69 decibels – **Fair /** Urban noise between 70 and 79 decibels – **Bad /** Urban noise equal to or greater than 80 decibels – **Terrible**
COMMERCIAL AND/OR TOURIST POINTS
DEFINITION - Refers to the existence of points that attract people to the region and contribute to a greater flow of pedestrians in the area. They can be considered social and/or tourist spots, squares, parks, shopping malls, museums, historical buildings and monuments, natural landscapes and the like.
SCORING SCALES - There are social and/or tourist spots that attract people from other cities – **Excellent /** There are social and/or tourist spots that attract people from other neighborhoods – **Good /** There are social and/or tourist spots that attract resident people of the analyzed area – **Fair /** There are social and/or tourist spots, but it is closed or abandoned or does not attract people – **Bad /** There are no social and/or tourist spots in the analyzed area – **Terrible**
TEMPERATURE
DEFINITION - The sensation of thermal comfort depends on a series of variables, such as environmental factors, clothing, metabolic load and activity performed. One of the environmental variables that influence pedestrians'

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sensation of comfort is air temperature. A temperature that helps the individual maintain a state of thermal comfort can help people choose walking as a mode of transport.
SCORING SCALES - Temperature between 9ºC and 26ºC – **Excellent /** Temperature between 0ºC and 9ºC or between 26ºC and 32ºC – **Good /** Temperature between -13ºC and 0ºC or between 32ºC and 38ºC – **Regular /** Temperature between -13ºC and -27ºC or between 38ºC and 46ºC – **Bad /** Temperature below -27ºC or above 46ºC – **Very Bad**
PRESENCE OF GRAFFITI, VANDALISM, ABANDONED BUILDINGS
DEFINITION - The indicator analyzes the occurrence of elements that can generate a feeling of insecurity in pedestrians by inferring the image of a violent and/or abandoned place.
SCORING SCALES - There are no lots with abandoned buildings, graffiti or signs of vandalism – **Excellent /** There are no lots with abandoned buildings or signs of vandalism, but there is graffiti on at least one facade in the segment – **Good /** There is only one lot with an abandoned building , signs of vandalism and graffiti – **Fair /** Two lots in the segment are made up of abandoned buildings, there are signs of vandalism and graffiti – **Bad /** Three or more lots in the segment are made up of abandoned buildings, there are signs of vandalism and graffiti – **Poor**

Source: Authors, 2024.

4.3 Category: 15-minute city

Table 4- Indicators for the 15-minute city category

DENSITY
DEFINITION - Evaluates population density calculated by the ratio between the total number of inhabitants of the urban area and the total area analyzed.
SCORING SCALES - There are between 35,001 and 45,000 inhabitants per km² – **Excellent /** There are between 25,001 and 35,000 inhabitants per km² – **Good /** There are between 15,001 and 25,000 inhabitants per km² – **Fair /** There are between 4,500 and 15,000 inhabitants per km² – **Poor /** There are less of 4500 inhabitants per km² or more than 45000 inhabitants per km² – **Terrible**
DIVERSITY (LAND USE)
DEFINITION - Diversity refers to the balance of land uses in the analyzed area. A diverse environment favors walkability, as the distances to carry out everyday activities are reduced. Consequently, diversity contributes to a greater sense of security and urban vitality through the flow of pedestrians at different times.
SCORING SCALES - There are 5 or more types of uses on the street – **Excellent /** There are 4 types of uses on the street - **Good** There are 2 or 3 types of uses on the street – **Fair /** There is only 1 type of use on the street (commercial) – **Bad /** There is only 1 type of use on the street (residential) – **Terrible**
PROXIMITY
DEFINITION - The indicator refers to the proximity between essential daily activities and the residential area. Living close to basic services contributes to an increase in walking trips and a reduction in spending (time and financial) on travel, in addition to reducing environmental impacts.
SCORING SCALES - There are 5 or more points of interest (school, supermarket, pharmacy, stores, institutional, services, among others) within a reachable distance of up to 15 minutes walking – **Excellent /** There are between 3 and 4 points of interest within a distance reachable within 15 minutes walking – **Good /** There are 2 points of interest within a reachable distance of up to 15 minutes walking – **Average /** There is only 1 point of interest within a reachable distance within 15 minutes walking – **Poor /** There are no points of interest within reach a distance reachable in up to 15 minutes walking – **Terrible**
SCANNING
DEFINITION - The indicator is relevant to the modified 15-Minute city concept. Digitization, especially during this COVID-19 period, has made it possible for people to work from home and communicate virtually. Digital solutions guarantee the updating of the three dimensions above. Digital tools offer different forms of modality, such as bike sharing, online payments, blockchain technology and emissions measurement and monitoring of traffic flows.
SCORE SCALES - The city has good internet coverage throughout its perimeter, has an application that provides detailed itineraries and bus schedules in real time, traffic light resynchronization according to the flow of pedestrians and vehicles, real-time weather data available in websites, applications or digital totems spread across the city – **Excellent /** The city has good internet coverage throughout its perimeter, has an application that provides detailed itineraries and bus schedules in real time – **Good /** The city has good internet coverage that possibility for residents to work remotely – **Fair /** The city has internet coverage, but it is of low quality or unstable for most of the day – **Bad /** The city does not have any type of internet coverage – **Terrible/non-existent**

Source: Authors, 2024.

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4.4. Category: security

Table 5- Security category indicators

LIGHTING
DEFINITION - Well-lit public space provides conditions for pedestrians to move around safely and comfortably. The indicator in question analyzes the luminosity across the entire sidewalk segment through the presence of lighting posts provided and managed by public authorities.
SCORING SCALES - There is public lighting directed towards the sidewalk and at crossings throughout the segment, with no broken lamps or obstructions by trees – **Excellent /** There is public street lighting directed towards the road, without broken lamps or obstructions by trees – **Good /** There is lighting public lighting directed to the sidewalk and at crossings throughout the segment, but with broken lamps or obstructions by trees – **Fair /** There is public street lighting, but only directed towards the road, but with parts obstructed or with broken lamps – **Poor /** There is no lighting public service on the road – **Terrible/non-existent**
PRESENCE OF PUBLIC SECURITY AGENTS
DEFINITION - The indicator analyzes the presence of police stations or municipal guard posts in the region and the presence of security professionals making rounds in the analyzed area.
SCORING SCALES - The area analyzed has a military police post and a municipal guard post, and there are security professionals making rounds daily – **Excellent /** The area analyzed has a military police post or a municipal guard post and there are security professionals security guards making rounds daily – **Good /** The area analyzed has a military police station or a municipal guard station or there are security professionals doing patrols daily – **Fair /** The area analyzed does not have a military police station or a municipal guard station and there are security professionals making rounds less than three times a week – **Poor /** The area analyzed does not have a military police post or a municipal guard post and there are no security professionals making rounds in the region – **Terrible/non-existent**
ROAD TYPOLOGY
DEFINITION - The indicator refers to the classification of the type of urban road, defined based on the speed limit allowed for vehicles to circulate on these roads. Road speed is a factor that affects pedestrian safety, since higher speed routes are more likely to result in accidents affecting pedestrians.
SCORING SCALES - Local Road or boardwalk – **Excellent /** Collector Road – **Good** / Arterial Road – **Average /** Rapid transit road – Bad **/** Interstate highway – **Terrible/non-existent**
CROSSINGS
DEFINITION - for pedestrians to move around the city in the form of a network, it is essential that they can cross from one sidewalk segment to another with comfort and safety. This indicator analyzes whether the crossings in the region meet the requirements.
SCORING SCALES - Crossings have pedestrian crossings, with traffic lights on collector and arterial roads or are roads with a low volume of motorized vehicles; there are ramps with an appropriate slope or the sidewalk is at the same level as the road – **Excellent /** The crossings have pedestrian crossings or the road has a low volume of motorized vehicles; there are ramps with an appropriate slope or the sidewalk is at the same level as the road – **Good /** Crossings have unlit pedestrian crossings or there is a road with a low volume of motor vehicles, a ramp with an appropriate slope or sidewalk at the same level as the street – **Fair /** Crossings do not have pedestrian crossings and there are uneven levels – **Bad /** Impossibility of pedestrians crossing – **Terrible/non-existent**
SIGNAGE FOR PEDESTRIANS
DEFINITION - The indicator analyzes the presence of road signs for pedestrians, which aims to prevent accidents and protect people traveling on the streets.
SCORING SCALES - On the street there are pedestrian crossings or elevated crossings, traffic lights for pedestrians (in the case of collector and/or arterial roads), tactile signage on the sidewalk, traffic signs or warning signs – **Excellent /** There are lanes on the street pedestrian crossings, pedestrian traffic lights, traffic signs or warning signs – **Good /** There are pedestrian crossings and traffic signs or warning signs on the street or it is a local road with a low volume of motor vehicles – **Fair /** A signage is deteriorated – **Bad /** There is no type of road signage - **Terrible/non-existent**
ROAD PROTECTION ELEMENTS FOR PEDESTRIANS
DEFINITION - The indicator refers to the percentage of the block face that offers protective elements to pedestrians in relation to motorized traffic. These protective elements act as barriers that contribute to the walker's feeling

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of safety. Parking lanes, green stripes at the edges of sidewalks, cycle paths, benches and parklets can be considered as road protection elements for pedestrians.
SCORING SCALES - 76% to 100% of the sidewalk segment offers protective elements – **Excellent /** 51% to 75% of the sidewalk segment offers protective elements – **Good /** 26% to 50% of the sidewalk segment offers protective elements - **Regular /** 10% to 25% of the sidewalk segment offers protective elements - Poor **/** There are no protective elements – **Poor/non-existent**
ROAD DISTRIBUTION
DEFINITION - The indicator evaluates the amount of road space dedicated to safe pedestrian circulation.
SCORING SCALES - Exclusive walking path (sidewalk) or complete streets with priority for pedestrians (shared, i.e., at the same level and reduced speed) in their entire dimension – **Excellent /** Segregated spaces (roads and sidewalks), however, with space distributed equally for motor vehicles and pedestrians: 50% of the space dedicated to sidewalks and cycle paths and 50% for vehicles – **Good** / Segregated spaces (roads and sidewalks), road space slightly wider than sidewalks (including on-street parking): 40 % of space dedicated to sidewalks and cycle paths and 60% to vehicles – **Fair /** Less than 20% of space is dedicated to pedestrians – **Poor /** Less than 10% of space is dedicated to pedestrians or there are no sidewalks and cycle paths – **Terrible/non-existent**
TRAFFIC CALM DEVICES
DEFINITION - This is traffic management through physical interventions in the road system, with the aim of acting on driver behavior by reducing the speed of motor vehicles, and consequently, providing more safety for pedestrians. Speed bumps, choke points, chicanes, narrowing of roads, roundabouts, speed cameras, are examples of traffic calming devices.
SCORING SCALES - The street has 4 or more traffic calming elements – **Excellent /** The street has 2 or 3 traffic calming elements – **Good /** The street has at least 1 traffic calming element that can reduce the speed of motor vehicles – **Fair /** The street has 1 traffic calming element, but it is not enough to reduce the speed of motor vehicles – **Bad /** There are no traffic calming elements on the street - **Terrible/non-existent**

Source: Authors, 2024.

4.5 Category: mobility

Table 6- Mobility category indicators

CONNECTIVITY
DEFINITION - The indicator refers to the density of intersections in the analyzed area, provided by a permeable urban design and with blocks sized to favor walking.
SCORING SCALES - The face of the court is up to 100 meters long – **Excellent /** The face of the court is between 101 and 120 meters long – **Good /** The face of the court is between 121 and 150 meters long – **Fair /** The face of the court court is between 151 and 200 meters long – **Bad /** The face of the court is more than 200 meters long - **Terrible/non-existent**
PRESENCE OF CYCLE PATH, CYCLE LANE OR CYCLE ROUTE
DEFINITION - The indicator analyzes the existence of dedicated or preferential spaces for cycling.
SCORING SCALES - There is a signposted cycle path, in one direction or two-way, with a separation that keeps cyclists protected from cars, there are also bicycle rental points – **Excellent /** There is a cycle lane (delimited space on the road itself, next to other vehicles), in one-way or two-way – **Good /** There is a cycle route (preferential space for cyclists located on the road itself, next to other vehicles), one-way or two-way – **Fair /** There is a cycle route but the preference is not respected and the space is commonly used by motorized vehicles – **Bad /** There is no space available for cyclists - **Terrible/non-existent**
INTEGRATION WITH PUBLIC TRANSPORT MEANS
DEFINITION - Good walkability can solve many adversities related to urban mobility, however, it needs to be integrated with other modes, such as cycling and public transport. Therefore, the indicator evaluates the connection and proximity to other transport networks, which, when well-integrated, makes the city more democratic and encourages the use of active and collective modes.
SCORING SCALES - The area has 5 embarkation/disembarkation points for conventional bus lines and a high or medium capacity transport station in the central region analyzed – **Excellent /** The area has 4 embarkation/disembarkation points for conventional bus lines and a high or medium capacity transport station on the edge of the analyzed region – **Good /** The area has 2 embarkation/disembarkation points for conventional bus lines – **Fair /** The area has 1 embarkation/disembarkation point for conventional bus lines – **Bad /** The area does not have embarkation/disembarkation points for conventional bus lines – **Terrible/non-existent**

Source: Authors, 2024.

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5 FINAL CONSIDERATIONS

Walkability analysis aims to provide a diagnosis of the urban space dedicated to pedestrians, and thus, direct improvements to insufficient points. More accurate diagnoses of walkability are the first step for urban managers to guide themselves more assertively and carry out interventions and allocation of public resources more efficiently.

Although any urban trip begins and ends by covering a section on foot, not every trip within a city is feasible to be completed by walking throughout its entire route. Therefore, encompassing relevant indicators for the 15-minute city model can help to better assess urban space on its microscale, where the greatest number of trips on foot takes place, whether to carry out essential daily activities or to connect with others. modes of transport.

The scoring scales of the indicators that make up the index were divided into five ranges (0.00, 0.25, 0.50, 0.75 and 1.00), which makes it possible to obtain more detailed results in each scenario. With this, we sought a more sensitive analysis of the evaluated locations, different from the results that could be obtained with a dichotomous scoring scale, for example.

The research contributes to the continuous advancement of methodologies for measuring and evaluating walkability, which aim to increase the use of active modes as a form of effective travel. For future work, it is suggested to validate the index through the opinion of a group of experts in the area and determine the weights that each of the 30 indicators represents for different groups of pedestrians, such as women, men and people with disabilities and people with disabilities. reduced mobility.

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