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Pedestrians Mobility on Public Sidewalks Evaluated by the IAAPE Method

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Abstract: This research aims to evaluate walkability as a strategy of urban mobility in relation to physical characteristics of accessibility and attractiveness from public sidewalks characteristics in the city of Passo Fundo/RS-Brazil using the IAAPE (indicators of attraction and pedestrian accessibility) method. The concept of walkability corresponds to the simple act of walking in a pleasant way along the footpaths. Therefore, the IAAPE method was used, which considers aspects of connectivity, comfort, conviviality, coexistence, convenience, clarity and commitment in relation to the space evaluated. In this study, 40 adults, elderly, pregnant and wheelchair subjects were interviewed for evaluating the importance criteria on public sidewalks for a given type of user. In general, reduced sidewalk dimensions and obstacle presence are the main displacement hurdles in most of the cases analyzed. Thus, improvements are needed to avoid stress situations that arise from daily routine, to encourage physical activities, accessibility, and the emergence of meeting and leisure points.

Key words: Walkability, mobility, public sidewalks, IAAPE, life quality.

1. Introduction

The development and expansion of cities, according to Refs. [1-12], are expressed in different ways, encouraging reflection on an urban mobility that generates access easiness for the population. In order to provide better access conditions to users, it is necessary to seek greater ease in pedestrian movement, according to Refs. [2, 3, 13].

However, for Refs. [13, 14], pedestrians flow should not be hampered in cities, thus the importance of thinking about accessible and adequate public sidewalks. In this sense, it is necessary to understand that sidewalk is considered as the "part of the track not destined to the circulation of vehicles, reserved for the pedestrian traffic and, when possible, the establishment of furniture, signalization, vegetation and other purposes" [15].

Free movement of pedestrians in the urban space, provided by public sidewalks, is extremely necessary since it encourages on foot displacements [2, 9, 13, 16]. However, according to Ref. [17], cultural factors can lead to a devaluation and lack of incentive regarding this mode of displacement.

In this same context, quality of paths developed for pedestrians is compromised and depreciated, due to the lack of design planning and necessary maintenance, which adds to lack of accessibility for pedestrians with different needs [8, 9, 18]. These obstacles to free access of public sidewalks cause a lack of walkability and jeopardize pedestrian safety that transits in pathways that do not have the necessary accessibility and space for safe circulation. It is important to

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remember that in order to enjoy a healthy life in the urban environment, it is necessary to follow certain standards for the population.

These standards are constituted by social and individual processes that are organized, taking into account general processes: human biology, the environment, ways of life and health system [16, 19, 20]. In these relations, the environmental factors are divided in two means of influence: the natural environment and the humanized environment, that is, the space modified by man.

Changes in the urban environment with the transformation of its landscape have direct and indirect impacts on population health, such as lack of adequate sanitary conditions in regions of high population density [20]. In this context, the urban environment must be conceived as a democratic space, and regarding mobility, allowing free, universal an secure access for all users [12, 21].

Thus, conditions of pedestrians access to certain routes for their displacement are defined as walkability which, according to Ref. [22], takes into account the accessibility of the urban environment and measures the ease in which people dislocate within the city. In this case, the indexes of walkability can directly influence predisposition that people have or would have to walk in certain places, evidencing the need to study the relevant aspects regarding attractiveness of walking displacements which, according to Ref. [23], "it is the fundamental means of displacement of any person to maintain their health".

Walkbility can be evaluated, according to Ref. [23], from seven indicators, also known as 7 "Cs": "connectivity" is based on the continuity of the route on the public sidewalk and in the greater integration between the urban network (quantity of other interest sites achievable in a certain amount of time); "convenience" is conceptualized as the sidewalk width necessary to accommodate the human flow and in the diversity of daily commerce and service uses, according to its location in the urban mesh; "comfort" can be summarized in the experience generated from the path to the user, which structure and quality of the flooring is analyzed (uneven, smooth, non-slip floor); "conviviality" is based on the attraction that this space has for other people, if it is only used as traffic or if there is a notable use to establish an experience, such as the presence of banks and kiosks; "clarity" consists on the ease of understanding the desired urban orientation for the user, notable sites and singular reference elements (square, towers, shops, etc.); "coexistence" establishes a clear separation between pedestrian and vehicle space, motorized or not, analyzing if there is a balance and ease of presence for both, considering the existence of both, and if there is balance; "commitment" is compliance with legislation and existing standards on accessibility in public spaces, equipment and buildings, as well as the standardization of interventions and solutions to improve urban space.

Concerning the importance of this theme, this research aims to evaluate the physical characteristics of accessibility on the patterns of walkability and population attractiveness, using the IAAPE (indicators of attraction and pedestrian accessibility) method, in order to diagnose the quality of public sidewalks surveyed in the city of Passo Fundo/RS, Brazil, considering aspects of connectivity, comfort, conviviality, coexistence, convenience, clarity and commitment.

It is important to mention that researches involving patterns of walkability are of fundamental importance, since, according to the 2010 Census of the Brazilian Institute of Geography and Statistics [24], 24% of the population have some deficiency, and according to Ref. [16], they require public sidewalks that allow pedestrian accessibility. It is also noticeable the increase in the number of elderly people, who already reach 11% of the Brazilian population, reinforcing the need for investments in the construction and maintenance of accessible sidewalks.

Furthermore, Brazilian legislation related to accessibility in buildings, relating to furniture, spaces

and urban equipment (NBR 9050) [25] should be taken into account when planning and constructing public sidewalks. This regulation imposes that public sidewalks must have two ranges of use: the first service range is intended for afforestation, installation of garbage cans and other urban furniture, with a minimum allowable width of 70 cm; and another one destined to pedestrian circulation, free of any obstacle, recommended width of 1.50 m, with a minimum allowable of 1.20 m.

The importance of research on users' access to walkability is demonstrated by the need to represent public sidewalks and to investigate how they influence and directly relate to pedestrian mobility in cities [12, 26]. This assessment encourages the need to rethink the city use, taking into account its development in order to recreate and integrate improvements. The development of improved public sidewalks reflects daily in the well-being of citizens who will use these spaces.

When the idea that cities were made for people, not for cars is recaptured [2, 9, 13, 24], public entities and responsible organizations are alerted so that practical measures are taken to improve these displacement spaces for users. Evaluating public sidewalks in a technical way and from the users' opinion of the system (adults, elderly, pregnant and wheelchair users), it is possible to diagnose the scenario and thus decide if there is a need for alterations and improvments in public policies.

2. Materials and Methods

For the evaluation of walkability patterns and population attractiveness, from the IAAPE (indicators of attractiveness and pedestrian accessibility) [27], certain public sidewalks along the arterial and collecting streets were considered in the city of Passo Fundo. The city of Passo Fundo, located in the state of Rio Grande do Sul, Brazil, needs increasingly more studies that trigger projects to implement improvements in most of its public sidewalks. Due to its population of approximately 197,800 inhabitants [24] and a fleet of 125,644 motor vehicles [28], it is noted that the city was not designed to accommodate such flows of pedestrians and vehicles, which increased from 65,256 in 2006 to 125,644 in 2016, arise of 92.5% [28].

Firstly, eight main routes were chosen for the research due to their high degree of vehicles and pedestrians flow. They are Avenues Brasil, Presidente Vargas and Sete de Setembro, and the streets Teixeira Soares, 15 de Novembro, Paissandu, Uruguai and Morom. Each roadway was divided into four sampling sites, to analyze the public sidewalk, according to Fig. 1. Thus, a total of 32 sites of analysis were accounted for, delimited by the TIN (triangulated irregular network) method, which requires a minimum of three sites to form triangles [29]. For greater precision, this research analyzed four sites per roadway, aiming to make a complete analysis of walkability in the public sidewalks.

Afterwards, a walkability diagnos in these sites was made based on the perception of the chosen users, through photographic records of 32 sites sampled; using the methodology described by Ref. [23], which allows to define, through images, the physical characteristics of each point.

A total of 40 interviewees aged between 18 and 82 years were interviewed, 10 adults (A), 10 elderly (B), 10 pregnant women (C) and 10 wheelchair users (D). Participants were included by a random convenience sample, with freedom of choice to participate or not in this research. A common schedule was set for all participants, where the interviewer conducted the discussion with each group separately to assess the quality of public sidewalks at different sites mentioned before.

In order to improve this contemporary scenario of accessibility in public sidewalks, there is a need for diagnosis and evaluation of the numerous issues that hamper displacements of pedestrians [12]. For this analysis, the IAAPE method [27] was chosen, which

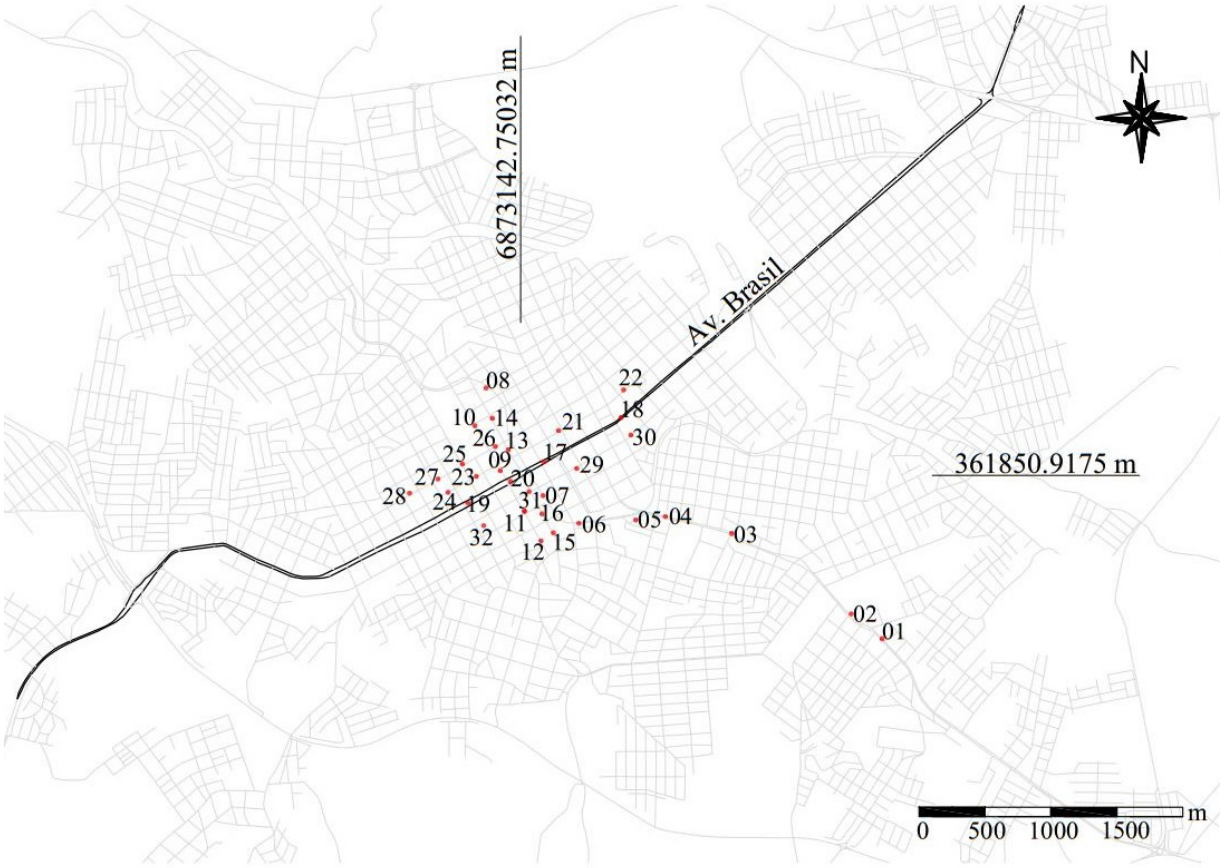

Fig. 1 Location of the 32 sites sampled on public sidewalks.

characterizes walkability criteria in urban environments. Concerting this method, two main points for cities improvement are considered: accessibility and attractiveness, using as an analytical basis, the aforementioned 7 "Cs". Each group of respondents discussed all categories of the 7 "Cs" for all 32 sites and reached consensus on a grade of importance ranging from zero (0) to ten (10). Each user group evaluated the sites through images projected in a room through a multimedia projector. All evaluated items and categories are represented in Table 1.

After the discussion, data were analyzed and the statistic mean of each category was generated. Subsequently, after calculating a total mean value, it was possible to evaluate the patterns of walkability and attractiveness in public sidewalks in the studied city by means of statistical analysis in SPSS23 through Spearman's correlation and variance analysis by the Mann-Whitney test among groups. This made it possible to suggest improvements in public policies aimed at improving public sidewalks.

3. Results and Discussion

3.1 Physical Characteristic Analysis of the Studied Sidewalks

The 32 sites (S) sampled represented in Fig. 2 were divided in S1, S2, S3 and S4 (Presidente Vargas Avenue); S5, S6, S7 and S8 (Sete de Setembro Avenue); S9, S10, S11 and S12 (Teixeira Soares Street); S13, S14, S15 and S16 (15 de Novembro Street); S17, S18, S19 and S20 (Brasil Avenue); S21, S22, S23 and S24 (Paissandu Street); S25, S26, S27 and S28 (Uruguai Street); and S29, S30, S31, and S32 (Morom Street).

Thus, it was possible to identify the physical relationship of these public sidewalks compared to walkability indexes composed by field analysis that, in

a systemic way, evaluates four specific sites in public sidewalks in each of the eight routes analyzed.

The first sites analyzed are situated in Presidente Vargas Avenue, which presents elevated vehicles flow, due to its connection with RS-324 (roadway) and it is also the access road to the city for people coming from other cities as Marau, Vila Maria and Casca. At Site 1 (S1), correlating with the 7 "Cs", it is notable that there is no comfort, coexistence and commitment in this location. The pathway does not reach the necessary dimensions for accessibility. According to NBR 9050 [25], compliance non-existence of this standard poses death risk for pedestrians by proximity to a high traffic avenue. The same occurs in S4, where and there is no coexistence, since the separation of pedestrians' space and cars is deficient (Fig. 2).

Table 1 Representation of IAAPE method using 7 "Cs" as an analytical base, adapted from Ref. [27].

Item	Category	Contextualization
Connectivity	C11	Density of paths (alternative routes, intersections)
	C12	Route continuity in which users will be able to move around the public sidewalk without interruptions
	C13	Path as linear as possible from origin to destination
	C14	Existence of accessible pedestrian infrastructure and noticeable pathway leveling and minimum width
	C15	Greater integration of urban networks and walkability pathway quality
Convenience	C21	Diversity of uses (shops, offices, dwellings, residences, parks, hospitals, health centers)
	C22	Adequate space without different directions of flows interference (coming and going)
	C23	Presence of obstacles
	C24	Quantity and density of daily commerce uses (food, beverages, banks, post offices, hospitals, health units)
	C25	Alternatives to overcome unevenness or significant slopes (ramps) that may hinder walkability
Comfort	C31	Users can see and be seen due to absence of walls or other types of physical barriers
	C32	Surface quality (regular or irregular pavement)
	C33	Climate shelters, which provide shadows, protecting from insolations and rainfall
	C34	Space sensitive quality (noises and odors)
	C35	Presence of roots suspending the surface of the public walkway
Conviviality	C41	Existence of meeting and stopping places (benches, tables and kiosks)
	C42	Existence of spaces with attraction effects (market, squares, gardens, hospitals)
	C43	Operation hours (housing, commerce, services and leisure)
	C44	Presence of non-functioning or abandoned physical spaces (house, buildings and walled areas that are perceived as not being used)
	C45	Greater population density and greater flows of users
Clarity	C51	Remarkable sites and elements for reference (squares, towers, gas stations, shops and hospitals)
	C52	Rectilinear course perception
	C53	Signalization and indications during course (traffic signs and lanes orientation)
	C54	Variability of architectural characteristics (colors, materials, façades treatment)
	C55	Built space understanding (whether it is central or peripheral, commercial or residential)
Coexistence	C61	Safety regarding pedestrian crossings (viability, interpretation, exposure to traffic)
	C62	User access to crossings to other main routes
	C63	Vehicle speeds appropriate in relation to pedestrians spaces (speed of movement and traffic volume)
	C64	Appropriate proportion of pedestrian and car traffic
	C65	Existence of car-invasion situations on the sidewalk (cars and bikes parked on the sidewalk, bicycle circulation)
Commitment	C71	Legislation compliance (public spaces accessibility)
	C72	Cleanliness (scattered garbage and animal waste)
	C73	Means of public participation (complaints or suggestions)
	C74	Initiatives and events that motivate walkability focused on health benefits
	C75	Infrastructure standards implemented continuously to improve sidewalks

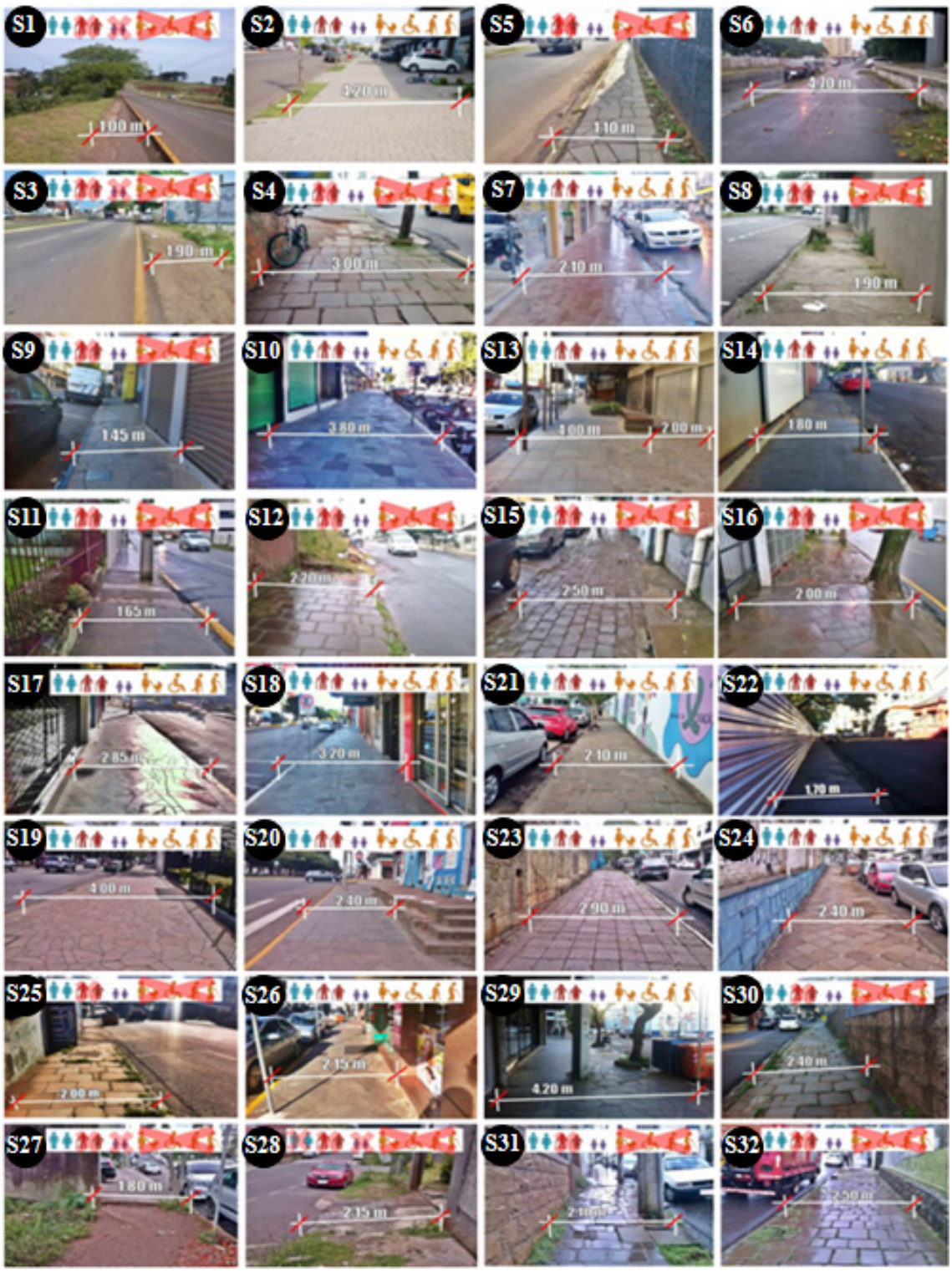

Fig. 2 Sidewalk walkability conditions in 32 studied sites (Sites 1, 2, 3, 4—Av. Presidente Vargas; Sites 5, 6, 7, 8—Av. Sete de Setembro; Sites 9, 10, 11, 12—Rua Teixeira Soares; Sites 13, 14, 15, 16—Rua 15 de Novembro; Sites 17, 18, 19, 20—Av. Brasil; Sites 21, 22, 23, 24—Rua Paissandu; Sites 25, 26, 27, 28—Rua Uruguai; Sites 29, 30, 31, 32—Rua Morom).

The lack of pavement structure and deficit is also repeated in S3 and S4, which hinder mobility of specific categories of users. However, in S2, it is notable that the location has a good structure and complies with issues related to connectivity, convenience, coexistence and commitment. It is important to state that this site is a recent construction in the neighborhood, which shows that new developments are being designed taking into consideration different characteristics of pedestrian users.

Analyzing the four sites on Sete de Setembro Avenue, it is possible to highlight that items of convenience, comfort, coexistence and commitment do not occur in S5 and S8, based on the size and structure of the sidewalks, which do not comply with the established normative [25]. Furthermore, it presents risks to population by the proximity with car traffic. On the other hand, on S6 and S7, it is possible to establish an adequate walkability, referring to comfort, commitment and convenience.

The next sites studied are located in Teixeira Soares Street (Fig. 2), which has a great importance of connection between the main avenue of the city and São Vicente Hospital; a place accessed not only by city inhabitants, but from people of the entire region, causing intense flow of cars and pedestrians daily. Although this local greater importance, accessibility issues can be found in S9, S11 and S12, where the width of the sidewalk and urban furniture end up being obstacles for a pleasant flow, making comfort and connectivity items nonexistent. While on S10, the situation is different and it is already possible to establish a higher level of walkability in this location.

At 15 de Novembro Street (Fig. 2), it can be observed that in S13, the recent construction of a commercial enterprise has remarkably respected width and structure to meet all different user needs, reaching optimal levels in all 7 “Cs”. However, this pattern is not repeated in S14, S15 and S16, where the concept of commitment is not adequate regarding the sidewalk width required by NBR 9050. In addition to that, there is a lack of comfort, due to irregular pavement, that makes accessibility of users with reduced mobility impossible.

According to Refs. [12, 21], cities should be designed for users with reduced mobility accessibility, in order to guarantee insertion patterns of these people in relation to the built environment. This would be of paramount importance, as it would allow universal access through public sidewalks in areas of commerce, service and leisure.

On Avenida Brasilsites (Fig. 2), which is the main city avenue, it is possible to affirm that its walkability makes the pedestrian path pleasant, considering connectivity and convenience, since it connects many commercial points, markets and schools in the city. There are good assessments of comfort, clarity, coexistence and commitment in all sites analyzed (S17, S18, S19 and S20). However, conviviality is not present, since there are no spaces to generate attraction so that people can stop over and enjoy living or contemplating spaces. The lack of benches or kiosks in the public space makes the routine repetitive, since according to Refs. [16, 24], when the urban infrastructure equipment (benches, garbage cans, lighting) does not meet population needs, urban life becomes inefficient.

Paissandu Street is part of the city’s main urban network, and it is parallel to Brasil Avenue and connects schools and hospitals. When analyzing Sites S21, S22, S23 and S24 (Fig. 2), considering the 7 “Cs” concepts, a pleasant walkability is observed in these sites, with the exceptionof S22, since its dimension is only 1.70 m, which hinders user traffic in peak hours. According to Kunz et al.’s survey [17], it shows that in one hour, the number of pedestrians using this sidewalk reaches approximately 720 people.

Paralell to Paissandu Street, Uruguai Street is another important main access route and connects pubic hospitals and one of the best orthopedic hospitals in the region. Analyzing S25, S27 and S28 (Fig. 2), it is

perceived that accessibility is ineffective, causing health risks for those who have reduced mobility, who are forced to use the street and divide the space with cars to access the hospital. Only at S26, suitable levels of walkability are noted.

In the central part of the city, Morom Street has a great commercial importance and has a high pedestrian flow, reaching 1,750 people per hour in peak hours [17]. When analyzing S29, the presence of some obstacles in the middle of the course was detected. Nonetheless, pavement and dimension of the sidewalk establish a pleasant walkability experience related to comfort, clarity and connectivity. This experience is not repeated throughout the route, since S30, S31 and S32 present deficient and irregular pavements that make the path inaccessible to users with restricted mobility, despite the width size that promotes accessibility.

3.2 Descriptive Sample Analysis

Descriptive statistics shows that the 40 participants have an average age of 39.5 (standard deviation: 18.2) and average income of two minimum wages. The majority (32.5%) has completed higher education and 22.5% did not complete elementary education. The mean distance traveled by the subjects is 659.03 m/day and they perceive their happiness, on average, as 8.4 (SD: 2.1) (on a scale from 0 to 10).

By statistic correlation, it was verified that the higher the participants' income, the higher the education (p: 0.00, r: 0.5) and the tendency to own a motor vehicle (p: 0.00, r: 0.4).

It was also found that the higher the interviewed education, the smaller the distance they tend to travel daily (p: 0.02; r: -0.3). This is discussed in Al-bishawi, Ghadban and Jørgensen's research [16], in which population with higher education tend to occupy administrative positions and are increasingly distant from physical efforts.

Further statistical analisys revealed that the greater the age (p: 0.00; r: 0.6), the greater the distance covered by the interviewees. The lower the educational level (p: 0.02; r: -0.5), the lower the degree of happiness (p: 0.05; r: -0.3). According to Pollard and Wagnild [12], people with higher academic degrees have lower difficulties in obtaining better paid positions in society, which increases their rates of happiness.

Regarding walkability, the walking path used by the subjects may influence happiness, since discomforts can be caused by the walkability coefficient, which in turn can cause decline in happiness [12, 16]. Another hypothesis raised during the research was that variables related to means of walkability, such as the use of a motor vehicle, manual or non-manual wheelchair, could impact daily traveled distance and the degree of happiness.

Initiatives and events that motivate walkability towards benefits in quality of population life (C74) obtained an average of 3.99 out of 10, showing a low perception by the users regarding initiatives motivation towards walking displacements. This figure goes against what was stated by Moura, Gonçalves and Cambra [23], "walking is the fundamental means of displacement of any person to maintain their health" and, given the importance of this theme, it is important to diagnose and answer questions about how are the walkability conditions and how people use certain spaces for displacement in public sidewalks.

This reality is related with the infrastructure standards implemented continuously to improve sidewalks, in order to make it easier for the population to enjoy an improved walking system (C75). According to Manoj and Verma [11], Pollard and Wagnild [12] and Grub, Neckel, and Portella [30], thinking about infrastructure improvements in public sidewalks is of fundamental importance, as it is a matter of commitment to the population.

4. Conclusions

Walkability in the analyzed public sidewalks is linked to factors that are directly related to a healthier city, by the items of "connectivity", "convenience", "comfort", "conviviality", "clarity", "coexistence" and

"commitment". Using IAAPE method, with a focus on the central area of the city of Passo Fundo/RS, it was observed that the pleasant experience and accessibility fade away as routes move away from central areas, rendering the displacement impossible for various groups of users.

Most of the time, walkability becomes non-existent because there is no structure that allows mobility in urban spaces. Remembering the idea that cities were made for people, not for cars, it is crucial to draw attention from public entities and responsible companies so that concrete actions are taken to address projects to improve pedestrians' experience, generating greater pleasure and happiness to the people when using the urban space.

In this sense, the first proposal of improvement concerns sidewalks structure: width, quality and urban furniture need makeovers, since they do not provide accessibility in the majority of sites sampled in this study. For this, it is suggested the creation of municipal legislation that determines to the establishment owner, after being audited, to adjust his sidewalk, being the city hall incumbent for its inspection.

It is worth observing that in the central areas of the city, where people flow reaches higher levels, such as on Teixeira Soares Street, infrastructure is deteriorated, due to nearby buildings that do not respect the sidewalk width of 2.40 m. In order to make users' mobility possible on the sidewalk, it is suggested that parking spaces removal should be considered, in order to increase the width of the sidewalks, along with the implementation of bicycle lanes, influencing leisure practices.

It should be emphasized that Brazil needs to rethink its mobility strategies, since in the last eight years, it increased its automobile fleet by 167.76% [28]. If this path continues, it may be heading for a route with no return. According to Puel and Fernandez [2], Polo et al. [9], and Kunz et al. [17], a better solution for cities may be pedestrian mobility and alternative transportation, such as bicycle use.

Another issue that can be improved is related to signalization. This is a responsibility of the public transit officials, and needs to be repaired urgently so that users with reduced mobility have their accessibility guaranteed during their journeys.

Likewise, public sidewalks need attractiveness, with the purpose of stimulating urban spaces conviviality. For that, it is suggested the installation of points of interest or contemplation, such as public benches, so that it can enhance users' experience. This can favor these public spaces with walkability and commerce increase.

Since this was a pioneer study in Brazil, another pertinent fact worth mentioning was the researchers' concern regarding the different groups of interviewees: whether these meetings would be effective and applicable, or it was just going to spend their time with theoretical research. Recently in Portugal, where the IAAPE method was developed, there were also doubts from the population about its effectiveness. However, this method has proved to be a very efficient tool to evaluate factors of walkability (connectivity, convenience, comfort, conviviality, clarity, coexistence and commitment), to think and to apply improvements that contribute to the users' health.

As the mean value found in all analyzed items among the 32 sites sampled in the city of Passo Fundo was 5.83, it demonostrates a low figure and shows that the city needs to improve its walkability standards on public sidewalks. This evaluation of IAAPE could be applied to all Brazilian cities, since it allows knowing the mean value of importance of each item, due to the suggestions made by each group of respondents, and thus identify what can be improved in the city.

These improvements could avoid stress coming from daily routine; encourage practice of physical activities, such as walks on public spaces;promote security and accessibility for users; and stimulate emergence of meeting and leisure points [11]. Furthermore, it contributes to accident prevention, such as running overs and falls. With these measures in place, people

can have more harmony in moving around in the urban centers.

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