Proposal of a Social Index for Sidewalk Quality in Large Brazilian Cities

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ABSTRACT: The concentration of the urban population and the dynamics of cities present challenges to the municipal governments in their task to extend and conserve paved paths for pedestrians, especially in metropolises such as Rio de Janeiro where the integration between two or more modes of public transport is performed almost entirely on the surface and through bus lines, requiring the use of sidewalks more often. Although the Federal Constitution addresses the themes regarding accessibility in buildings and urban mobility, public actions for traffic solutions still favor motorized modes. Without proper conservation, sidewalks with holes and bumps are all over the city. Lack of access ramps for people with reduced mobility and misplaced newsagents reduce the pedestrians' flow capacity. It is undeniable that for the management of urban sidewalks, planning and related administrative actions need techniques that take into account the dynamics in place of empirical solutions. This research proposes a sustainable pavement model that prioritizes the social and institutional dimensions of the complex represented urban reality. A social index for sidewalk quality could help citizens and the public authorities to monitor and diagnose the conservation of sidewalks in order to take in due time the required actions to guarantee good conditions of urban mobility for pedestrians in large cities.

Keywords *Urban sidewalks; Urban infrastructure; Urban mobility; Social index for sidewalk quality*

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1. INTRODUCTION

Pavements for pedestrians were object of attention of government since the 17th century, when cities still had no motor vehicles. In the city of Rio de Janeiro, capital of the Brazilian empire, "in 1870, a new urban structure was in process, in total harmony with transportation; the city expanded due to the capacity of the transport network to ensure transportation of the population" (Silva, 2008). Figure 1 exhibits the granite sidewalks of Ajuda street, in the proximities of the municipal theater of Rio de Janeiro, in the early 20th century. They offered good comfort and safety conditions even for current demand levels. This example represents a significant advancement in pedestrian infrastructure in comparison to pavements that still prevailed at the time, as the "pé-de-moleque" (boy's-foot, a Brazilian candy made with crunched peanuts) that emerged in colonial times, still present in neighborhoods of Rio de Janeiro and other historical cities of Brazil. Figure 1 also shows a segment in "pé de moleque" on the current Rio Branco avenue, discovered in 2015 upon construction of the light rail vehicle (VLT).

Figure 1. (Left) - Ajuda street at the beginning of the 20th century with sidewalks in granite stones; (right) - Stone sidewalk in "pé-de-moleque" style on Rio Branco avenue, Rio de Janeiro.
Sources: www.rioquepassou.com.br/andrédecourt/wp-content/imagens/
Jornal O GLOBO g1.globo.com/rio-de-janeiro/noticia/2015/10/historico-achado-em-obra-do-vlt-e-parcialmente-destruido.html

Currently, sidewalks may be considered an indicator of human development, within the sustainable human mobility dimension, defined as the displacement manner that prioritizes the individual, producing minimal energetic cost with significant reduction of pollutants emissions and noise levels, restricting the use of cars and decreasing their speeds.

In this scenario, wherein sustainability is considered a guideline for urban development policies, which have among their purposes equity and social justice in the appropriation of land, resources and the use of road space, city walking gains more importance (Gondim, 2001). In Brazil, where more than 80% of the population lives in cities, how does the municipal public administration act on the current sidewalks infrastructure? Could a sidewalk quality index serve as a tool to the manager and the proper population, through residents associations to diagnose and monitor the quality of sidewalks? An attempt to answer these important questions is the aim of the present work.

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2. DIMENSIONS OF A SOCIAL SUSTAINABLE SIDEWALK

The sustainable urban infrastructure, even without directly dealing with environmental issues (such as the consumption of resources and energy) has increasing importance to society. "Mobility is the condition for checking social inclusion and quality of life indexes, in that it also enables or not the connection to social and economic opportunities" (Guimarães, 2012).

According to the Ministry of Cities (Brazil, 2016), sustainable mobility is the main link between transport, circulation and urban development policies. Although the term sustainable mobility reflects the concern with the transportation system on which society began to depend on, the big question to be answered is whether the existing structure will continue to work in order to meet the population in its need for mobility. The urban infrastructure for non-motorized transport is a component of this structure, where sidewalks are the basic link that connects the citizen with the transport system.

Sustainable sidewalks, in addition to containing properties that enable a pavement for a long service life, and compatible with conservation procedures suitable to the precepts of sustainability, must meet some social criteria (minimum safety, minimum comfort and minimum accessibility) and be under the care of a management able to guarantee its functionality through guidelines, operational capacity and management instruments. There is desire for a sustainable sidewalk model that contemplates and adds aspects of contemporary urban reality in the light of the diversity of concepts and recent developments in the areas of urban planning, public administration, environmental and urban engineering in the social and institutional dimensions.

2.1 Social dimension

Some concepts are presented for evaluation and monitoring of sidewalks by the public administration in such a way that governance decisions, in the medium term, and conservation actions in the short term, are prioritized.

2.1.1 Minimum Security

Anti-slip floor surface suitable for preventing slipping but with rolling comfort for wheelchair users and those visually impaired; sidewalk signaling - visual, tactile and sound according to the definitions of NBR 9050 (ABNT, 2015); signs for access ramps, garages and crosswalks, according to Brazilian Traffic Code (Brazil, 1997); presence of traffic lights for pedestrians; night lighting - NBR 5101 (ABNT, 2012) sets the minimum luminous flux for sidewalks at 3 lux for light routes and 5 lux for moderate pedestrian movement at night.

2.1.2 Minimum Comfort

In this essay, minimum comfort is understood as flow and speed conditions offered by the sidewalk do that the pedestrian has no difficulties or impediments to displace due to narrowing of passages, presence of obstacles, flood points, etc.

Free lane - defined by NBR 9050 (ABNT, 2015) as destined exclusively for pedestrian circulation, with minimum width of 1.20 m. In the city of Rio de Janeiro the free lane is established at 1.50m. The space between the free lane and the car lane constitutes the service lane, destined to landscaping, access ramps for vehicles, lampposts, traffic signs

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and street fixtures. It must have minimum width of 0.75m with the measurement of 1m being recommended for Rio de Janeiro;

Permeability - modern engineering seems to have adopted concrete as the standard coating for sidewalks (precast plates, hydraulic tiles, interlocked blocks) as in the technical specification for sidewalks in the city of São Paulo (São Paulo, 2016), possibly due to its availability and compressive strength and abrasion resistance characteristics. In relation to urban soil permeability, a better selection would be draining materials that allow rainwater passage, reduce the flow speed to the rain water collection networks, assist upon fighting floods and allow reuse water collection.

Green streets - trees, flower beds and lawns improve the environmental condition for those that walk on urban streets. Cities have been adopting solutions that incorporate green areas to enhance climatic and environmental conditions, with set up of parks, implementation of green corridors and urban arborization programs. The selection of vegetation must be careful, with leafs with size greater than the opening of rainwater drain grates and checking root growth type: horizontal roots may damage the finish and deep roots, depending on the location of planting, may cause damage to underground pipes.

Markers and interferences that reduce the width of the free lane (landscaped flower beds, poles, street fixtures, newsstands) or overhead obstacles (signs, marquees, vegetation, lanes less than 2.10 m in height). In the city of Rio de Janeiro the installation of landscaped flowerbeds and markers depend on municipal authorization (Rio de Janeiro, 2012) to avoid interference with the pedestrian circulation free lane.

Conservation of sidewalks – in Rio de Janeiro the responsibility for cleaning, maintenance or construction of sidewalks is of the condominium, owner of the real estate or land (Rio de Janeiro, 1988).

2.1.3 Minimum accessibility

Longitudinal slope of pavement at maximum 8.33% (1:12) and transversal pavement slope at maximum 3% according to NBR 9050 (ABNT, 2015); sidewalk abasement, to facilitate the transition from the public road to the sidewalk, should be lowered in the direction of flow, with no gap between the end of the rolling surface abasement, marked with crosswalk or traffic light if there is pedestrian crossing forecast; elevated pedestrian crossing, allowing movement in level between opposite sidewalks, must be flush, with no water passage interruption and comply with the technical specifications of NBR 9050 (ABNT, 2015).

2.2 Institutional dimension

The engineering services warranty with high quality and useful lifetime levels compatible with investments made depends on compliance with laws that translate principles and collective and individual guarantees and technical standards set up by experts. The implementation of these guidelines stems from the degree of organization of the institutions responsible for urban planning and management instruments. To this end, institutions must seek the efficiency, which as a constitutional principle, "does not only reach the public services provided directly to the collective, but must also be observed in relation to internal administrative services of the federative entities and entities linked to

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them" (Carvalho Filho, 2010). In the pursuit of efficiency, institutions must have guidelines, operational capacity and management instruments.

2.2.1 Guidelines

Laws, technical standards and director plans are needed to provide technical and legal support for institutions to engage upon planning, elaboration and execution of projects. In urban centers sidewalks must comply with the minimum requirements defined by the Brazilian Traffic Code (CBT) and also by the urbanization plans of the respective municipality, mostly as to what regards environmental and accessibility aspects. Article 68 of the CBT (Brazil, 1997) presented developments in pedestrian and cyclist protection such as, for example, “in the works of art to be built, there must be forecast for a pedestrian walk, which must not, in such conditions, use the shoulder” (Article 68, § 5th) and “cyclists on foot pushing their bicycle are equivalent to pedestrians when it comes to rights and obligations” (Article 68, § 1st).

The Brazilian Technical Norms Association presents the regulation on sidewalks in NBR 12.255 (ABNT, 1990) and in NBR 9.050 (ABNT, 2015). The Federal Constitution grants to the municipalities the competence to legislate on local interest matters and carry out the urban development policy, aiming at full development of city functions. The municipality of Rio de Janeiro elaborates its Sustainable Urban Mobility Plan - PMUS (Rio de Janeiro, 2015) which must guide public investments in the city’s transport infrastructure for 10 years, as of 2016, with integration of motorized and non-motorized modes, prioritizing public transport, displacement on foot and bicycle and greenhouse gas emissions.

2.2.2 Operating capacity

The efficiency of public service performance depends on entities comprised by technically empowered people that act in cooperation to assess public administrators upon priority technical matters, in permanent and ongoing manner, for the sound operation of systems under their jurisdiction. The lack of knowledge of technical standards for technological control can be common among public fiscal agents. Services such as asphalt paving, concreting or mortar for lining present a useful lifetime shorter than those specified in project, while the parameters of their constituent components (granulometry, dosage, homogeneity, etc.) and application conditions (temperature, tools and equipment, transport time, etc.) are not controlled. In the absence of technical teams to follow up the project, a simple blockage of the public drain network, for example, can consume days to be diagnosed, if there is no file of underground infrastructure. Decision-making, on several occasions, is on account of the proper technicians of the contractor (Novo, 2003).

2.2.3 Management instruments

To survey the services requested by the population of Rio de Janeiro, the Municipal Conservation Secretary (Seconserva) uses a telephone service (1746) for citizen demands. There are no quality indicators for services performed, just compliance goals: 7 days for pothole repairs, 7 days for clearings and 15 days for other conservation services. Requests are analyzed and monitored in light of such compliance terms; when exceeded, the system issues alerts (Brandão, 2016).

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3. INDEXES FOR EVALUATION OF SIDEWALKS

Ferreira and Sanches (2001) proposed the SQI - Sidewalk Quality Index considering the following consecutive stages: in the first, the most relevant quality indicators are selected, such as safety (which analyses the possibility of conflict among pedestrians and vehicles), maintenance, effective width, security (pedestrian vulnerability to robberies and assaults) and visual attraction, granting points according to the level of services performed; in the second one, weights are attributed to each of the previous quality indicators according to the perception of their respective importance by the pedestrians, and may vary from 1 to 5; the final stage consists of calculation of a pondered average of partial results for estimation of the SQI.

Keppe Jr. and Ferreira (2008) defined the SCAI - Sidewalk and Crossing Accessibility Index to estimate the mobility and accessibility degree for people with special needs, wheel chair users or the elderly. The same methodology as the IQC was employed, but with the selection of the following indicators of physical and environmental quality of infrastructure: comfort (effective width, longitudinal slope, transversal slope, type of flooring material); security (existence of signs and ramps, vehicle approximation perception, vehicle flow, surface conservation status, view of oncoming vehicles downstream crossing the sidewalk); environment (street arborization, aesthetics, location, lighting, depth vision).

The SISQ - Social Index for Sidewalk Quality proposed in the present work incorporates the social and institutional dimensions in the diagnostic of minimum physical and operating conditions of the infrastructure. The selected quality criteria and indicators in each dimension were mentioned previously (sections 2.1 and 2.2) being listed in Table 1 with the corresponding pondering factors for normalization of grading scales of the index calculation, according to equation 1.

$$SISQ = \left(\frac{\sum Sec + 3}{30} + \frac{\sum Comf + 11}{30} + \frac{\sum Acc + 2}{10} + \frac{\sum Cons + 25}{25} \right) / 4 \qquad (1)$$

where *Sec, Comf, Acc* and *Cons* refer to security, comfort, accessibility and conservation criteria, respectively.

The practicality of scoring the indicators that make up each part of SISQ and the easy understanding of the calculation method make the SISQ a mechanism for appropriate participation by ordinary citizens wishing to manifest themselves about the quality of infrastructure of sidewalks, expressing their level of satisfaction through diagnostics for corrective action in the short and medium term.

Mechanisms for individual participation, according to Cortes (2011), allow citizens to express their opinions on services and goods offered by the municipality or whose provision is regulated by the municipal government. Examples are services that receive suggestions and investigate complaints online or over the phone such as the crime stopper service or the municipal ombudsman agency.

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Table 1– Criteria and indicators for the Social Index for Sidewalk Quality

Criteria	Indicator	Punctuation		
Minimum security Min=-3 Max=27 Scale = 1:30	Non-slip floor	Ceramic or flat granite	0	Single choice
		Slate	2	
		Ceramic brick, hydraulic tile, interlocked elements, draining floor, Portuguese stone	3	
		Rough granite, soil-cement	4	
		Concrete or precast concrete plates	5	
	Signaling	Absence	0	Multiple choice
		Garage exits with visual and sound signals	1	
		Ramps signs	2	
		Tactile floor	2	
		Crossing	3	
		Pedestrian traffic lights	3	
		Timer Traffic lights for pedestrians	4	
		Traffic lights with sound for pedestrians	4	
	Lighting	Tree canopy preventing the incidence of artificial lighting (need for specific project)	-2	Multiple choice
		Less than 3 lux	-1	
		3 to 5 lux	2	
		Over 5 lux	3	
Minimum comfort Mín=-11 Máx=19 Scale=1:30	Free range	Ceramic or flat granite	-2	Choose one
		Slate	1	
		Ceramic brick, hydraulic tile, interlocked elements, draining floor, Portuguese stone	2	
		Above 1,80m	3	
	Permeability	Absence of any element that contributes to the flow; need for design and construction of drainage structures for	-2	Multiple choice
		Construction, garden, lawn	3	
		Culvert presence	4	
		Floor drainage	5	
	Afforestation	Absence	0	Choose one
		Planting minimum	2	
		Planting abundant	3	
	Bollard	Presence (outside the norm)	-1	Choose one
		Absence	0	
		Presence (as Standards)	1	
	Interferences	Over 50 % of the employed effective width	-5	Multiple choice
		% to 50 % of the employed effective width	-3	
		-25 % of the employed effective width	-2	
		Aerial obstacles below 2.1m	-1	
		No interference	0	
Minimum accessibility Min=-2 Max=8 Scale = 1:10	Longitudinal inclination	Over 8.33% (1:12)	-2	Choose one
		Less or equal to 8.33% (1:12)	2	
	Transversal inclination	Above 3%	0	Choose one
		Less or equal to 3%	2	
	Sidewalk abasement	Absence	0	Choose one
		Abasement with ramp	2	
	Elevated lane at crossing	Absence	0	Choose one
		Presence	2	
Management Min=-25 Max=0 Scale = 1:25	Conservation	Large presence of potholes	-5	Multiple choice
		Traffic light for pedestrians with faulty bulb	-4	
		Pole with faulty lamp	-4	
		Manhole visibly blocked	-3	
		Presence of trash or debris	-3	
		Gap, irregular depression or elevation	-2	
		Crosswalk paint heavily worn out	-2	
		Coating with noticeable wear or cracks	-1	
		Tactile floors with flaws (broken or loosened plates)	-1	
		Well-preserved sidewalk	0	

Source: Own authorship.

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4. APPLICATION OF THE SOCIAL INDEX FOR SIDEWALK QUALITY IN THE CITY OF RIO DE JANEIRO

The Social Index for Sidewalk Quality was applied upon analysis of sidewalks in several public venues in the city of Rio de Janeiro, including a segment of Pasteur avenue, at Urca neighborhood, recording the main quality indicators given in Table 1, as shown in Figure 2.

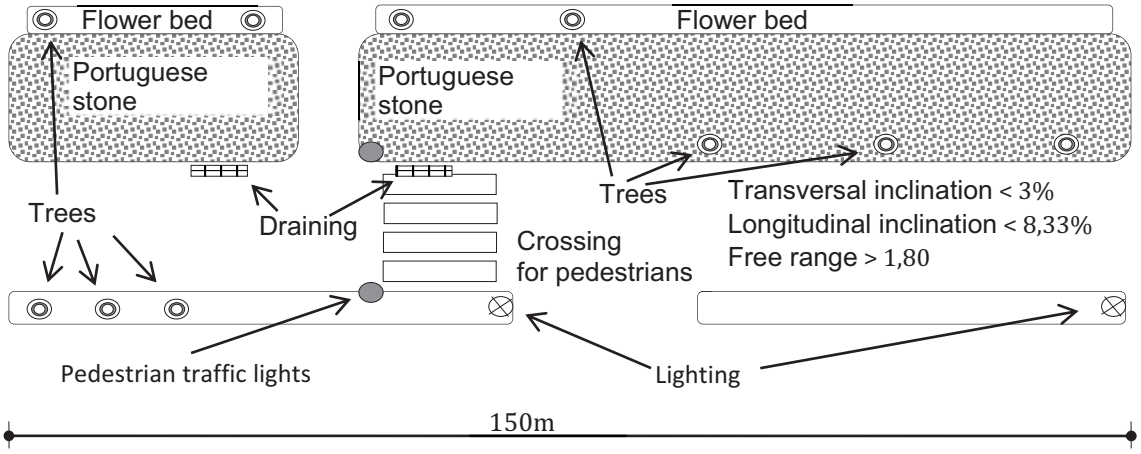

Figure 2. Quality indicators in a 150m segment of Pasteur avenue, Rio de Janeiro.
Source: Own authorship.

The indicators taken into account upon assessment of the sidewalks on Pasteur avenue, in the segment comprised between the General Tiburcio square and the UNIRIO University, with the respective scores shown in Table 2, resulted in 11 points for the minimum safety criteria, 17 points for the minimum comfort criteria and 4 points for the minimum accessibility criteria. The management criteria did not score.

Table 2– Social Index for Sidewalk Quality applied on Pasteur avenue, Rio de Janeiro.

Criteria	Indicator	Punctuation	
Minimum security	Non-slip floor	Portuguese stone	3
	Signaling	Crossing	3
		Pedestrian traffic lights	3
	Lighting	3 to 5 lux	2
	Total		11
Minimum comfort	Free lane	Above 1.80m	2
	Permeability	Worksite	3
		Manhole or gutter in segments shorter than 100m	4
		Draining floor	5
	Urban forestry	Abundant cultivation	3
	Marking	Absence	0
	Interferences	None	0
	Total		17
Minimum accessibility	Longitudinal inclination	Less or equal to 8.33% (1:12)	2
	Transversal inclination	Less or equal to 3%	2
	Sidewalk abasement	Absence	0
	Elevated lane at crossing	Absence	0
	Total		4
Management	Conservation	Well-preserved sidewalk	0

Source: Own authorship.

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These partial results are plotted onto the graph in Figure 3, with the score on conservation marked on the axis of ordinates, indicating the degree of urgency for conservation interventions, and the total score of each criterion in the abscissa axis, indicating the level of need for medium and long term actions related to the project.

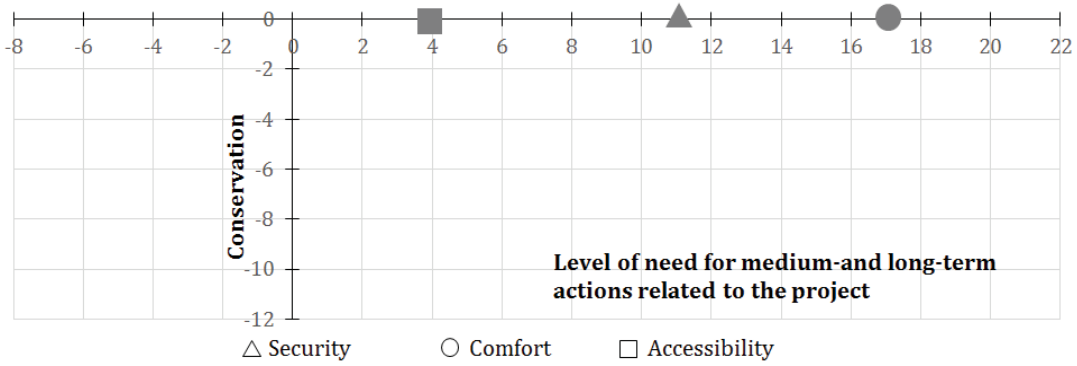

Figure 3. Criteria levels for set up of the sidewalk project for Pasteur avenue, Urca, Rio de Janeiro
Source: Own authorship.

The scores in Table 2, when inserted into equation 1, allowed the calculation of the normalized value of SQSI between 0 and 1. The conservation level of the sidewalk (management criteria) participates in the calculation as a reduction factor because it will always be negative when non-zero.

$$SQSI = \left(\frac{11+3}{30} + \frac{17+11}{30} + \frac{4+2}{10} + \frac{0+25}{25}\right)/4 \quad (2)$$

$$SQSI = (0.47 + 0.93 + 0.6 + 1)/4 = 0.75$$

The final result for SQSI indicates that the assessed sidewalk is overall in good conditions. Nonetheless, the analysis of each portion of equation 2 reveals that the level of project design in relation to safety criteria (0.47) is inferior to others, while the sidewalk project for Pasteur avenue received close attention in terms of comfort (0.93).

5. CONCLUSION

Sidewalks can be considered an indicator of human development, with consideration of sustainability in the concept of urban mobility. The Social Index for Sidewalk Quality (SISQ) was introduced in this work aiming at serving as a tool for municipal public administrations to diagnose and monitor the quality of urban sidewalks.

The index has been set-up based on several indicators pertaining to the social and institutional dimensions, and with their estimate possibly being extended to also comprise the environmental dimension (use of low-carbon materials including considerations of life cycle, new building techniques, etc.) and the economic dimension (availability of adequate manpower for construction and maintenance of sidewalks as Portuguese stone lining, for example, requires specifically trained professionals; materials with extended useful lifetime; low power consumption on maintenance of sidewalks; etc.).

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SISQ is easy to understand and to be applied. It can be a very useful tool to exercise good governance in public maintenance service, because citizens can help the public manager to diagnose and monitor the conservation of sidewalks in Brazilian cities.

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