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Pedestrian environment quality assessment for promotion of urban mobility in Portuguese medium-sized cities

Resumo

This text is supported in an international bibliographical survey on quality indices of the pedestrian environment. It discusses the definition of a methodology for the collection and analysis of the different components of the pedestrian environment (vehicle traffic, tours, occupation of soil and aesthetic and security aspects) to determine an index that can support the definition of proposals for the improvement of the pedestrian system. The text is based on a survey provided by a pilot field data which was used for the calibration and validation of the proposed methodology, as well as for the definition of a geographical information system for georeferenced graphic presentation of the obtained evaluation.

Palavras-chave

Urban mobility; pedestrian mobility; quality index; geographic information systems

Introduction

With the constant development of today's society, there is a wide variety of means to travel ranging from motor vehicles to non-motorized vehicles and pedestrian.

With regard to road traffic, its increase impairs the quality of life in urban areas, due to released emissions, noise or accidents. It is therefore necessary to ensure harmony between different networks and transportation modes by applying the concept of sustainable mobility, which promotes public and smooth transport modes.

According to Amoroso et al. (2012), walking is a highly sustainable transport mode for the following reasons:

1. all trips include at least one small journey made on foot, so some improvements in pedestrian infrastructures can/should be included in the budget of planned interventions on other transport networks;

2. reduces the amount of consumed fuel and therefore the emissions of gases into the atmosphere;

3. is an economic way to travel since it does not require investment in another transport mode or fuel; and,

4. promotes additional social and economic benefits, such as exercise, which makes people healthy, and leisure.

Thus, environments that allow and encourage people to walk contribute to healthier lifestyles, safer streets, social equity and environmental quality.

In order to evaluate and sustain interventions in the pedestrian environment, several approaches have been used. In general, these approaches are translated into an index that allows a global evaluation (scoring) of the environment and conditions offered to pedestrians, or the preparation and updating of pedestrian environment databases. For these approaches it is usually necessary to gather a set of parameters that allow assessing the physical safety of pedestrians, the existing pedestrian infrastructure and land use, and aesthetic and security aspects. In some approaches a subjective evaluation component with questions of personal opinion is considered.

Among the most used approaches are the Pedestrian Environmental Data Scan (PEDS) (Clifton, Smith, & Rodriguez, 2007), the Pedestrian Safety Index (PSI) (Asadi-Shekari, Moeinaddini, & Shah, 2015), the Pedestrian Environment Quality Index (PEQI) (SFDPH, 2008) and off-street Pedestrian Level of Service (HCM) (TRB, 2010).

Evaluation of existing tools

Three pedestrian environment audit tools (PEDS, PSI and PEQI) were reviewed to determine what were the most common indicators used in assessing the quality of pedestrian environment and which are the most suitable for the existing pedestrian conditions in Portuguese medium-sized cities.

The Pedestrian Environment Data Scan (PEDS) is one of the evaluation tools of existing pedestrian environments and was developed with the objective of collecting, in an organized way, a set of data related to the natural and constructed environment. PEDS was adapted from the Systematic Pedestrian and Cycling Environment Scan (SPACES), developed specifically for Australia, to be applied in the United States of America and allows assessing segments of the pedestrian network and footpaths. The used form has a total of 35 indicators divided into 4 sections, namely: environment, pedestrian infrastructures, road attributes and cycling and pedestrian environment. It also has a section with four subjective questions to evaluate the pedestrian environment as a whole (Clifton, Smith, & Rodriguez, 2007) (Livi, 2004).

Another audit tool, the Pedestrian Safety Index (PSI), assesses the basic needs of the pedestrian's security along their route, allowing the identification of existing problems and improvements to be made (Asadi-Shekari, et al., 2015). In the calculation of the PSI 24 indicators were considered, and its overall value was computed applying expression (1).

$$PSI = \sum_{i=1}^{24} c_i SI_i \qquad (1)$$

Where *PSI* is the Pedestrian Safety Index; *i* is the indicator number; *c* is the coefficient of safety indicator and *SI* is the Safety Indicator score.

The *c* coefficient reflects the importance of each indicator and is defined according to the depth degree of evaluation presented by indicator *i* and the number of authors that evaluate indicator *i* with the depth of evaluation *j*. Three categories were considered to classify the indicator's depth degree of evaluation. Regarding the score of the safety indicator (SI_i), it is calculated by comparing the safety standards defined by the authors, for the different road hierarchies, with the existing conditions of the street. The SI_i is translated by a number between zero and one, in which a higher compliance of the standards corresponds to value one and the non-adjustment results in 0. The value of PSI (in percentage) is given by expression (2) and the five considered classes, as well as their interpretations, are presented in Table 1.

$$PSI\ (\%) = \frac{PSI}{\sum_{i=1}^{24} c_i} \times 100$$

(2)

PSI% rating	Model score	Interpretation
A	80 – 100	Highest quality (very pleasant), many important pedestrian safety facilities present
B	60 – 79	High quality (acceptable), some important pedestrian safety facilities present
C	40 – 59	Average quality (rarely acceptable), pedestrian safety facilities present but possibility of improvement
D	20 – 39	Low quality (uncomfortable), minimal pedestrian safety facilities
E	0 – 19	Lowest quality (unpleasant)

Table 1: PSI interpretation
Source: Asadi-Shekari, Moeinaddini e Shah, 2015

The Pedestrian Environment Quality Index (PEQI) was developed by the San Francisco Department of Public Health and allows the pedestrian environment quality evaluation, as well as, get information about its intervention needs (SFDPH, 2008) (UCLA, 2013). It consists of two data collection forms, one for intersections and other for street segments. The intersection form consists in one section with 10 indicators. On the other hand, the street segment form incorporates 27 indicators divided into 5 sections: Vehicle Traffic, Sidewalks, Land Use, Safety and Aesthetic Qualities and Perceived Walkability. Each indicator has a weight according to the existing pedestrian conditions. The worse these conditions are, the lower its weight in the PEQI score. The sum of the weights assigned to an intersection or street segment gives the PEQI score (Table 2). With respect to intersections, the PEQI score is obtained as a function of the existence of traffic signs (Table 2).

The score is then adjusted to a range between 0-100 using expression (3). The score obtained allows the identification of existing pedestrian circulation conditions according to the classes presented in Table 3.

$$PEQI = \frac{(Unadjusted\ score - Minimum\ score)}{(Maximum\ score - Minimum\ score)} \times 100$$

(3)

Intersection formula	
Step 1	
With Traffic Signal: (pedestrian signals + no turn on red + crossing speed + scramble)	No Traffic Signal: (stop signs * 2)
Step 2	
Add above to: (crosswalks + ladder crosswalks + curb cuts + TCF count + additional pedestrian signs)	
Segment formula	
(number_lanes + two_way + speed_limit + TCF_count + sidewalk width + surface + obstructions + curb + curb cuts + trees + planters + seating + buffers + retail + public_art + graffiti + litter + ped-scale_lights + construction + abandoned_bldgs + bike_racks + vacant_lots + attractive + feels_safe + strong_odors + noisy + walkable)	

Table 2: PEQI intersection and street segment formulas

Score	Interpretation
0 – 20	Environment not suitable for pedestrians
21 – 40	Poor pedestrian conditions exist
41 – 60	Basic pedestrian conditions exist
61 – 80	Reasonable pedestrian conditions exist
81 – 100	Ideal pedestrian conditions exist

Table 3: PEQI score interpretation (UCLA, 2013)

All the methodologies presented have been developed with the same purpose, to collect information about the pedestrian environment allowing its evaluation and to gather information about possible improvements that could be made in order to make them more comfortable and safe for pedestrians. Nevertheless, there are some differences between the approaches presented. In the case of PEDS, its main disadvantage compared to the other approaches is that the collected data are not aggregated into a single index allowing a global assessment of the pedestrian environment and of the conditions offered to pedestrians. On the other hand, PEDS and PSI only consider collecting information on street segments, rather than PEQI, which incorporates two forms to separately assess the pedestrian environment at intersections and street segments.

Among the main advantages of using the PEQI index, it is highlighted the possibility to easily incorporate new specific indicators present in the evaluated area, as well as to redefine the existing indicator's weights from the original form.

While PSI is more directed to pedestrian's safety, PEDS and PEQI assess the pedestrian environment more broadly, including the perception of pedestrians about the environment that surrounds it through the incorporation of general issues and personal opinions in its forms.

The inclusion of an indicator related to the LOS offered by the segment, intersection or infrastructure in a global approach, as PEQI or PSI, could enhance the analysis and evaluation of pedestrian environments.

Development of a Portuguese index for medium-sized cities

PEQI was the framework used to generate a similar tool for Portuguese median-size cities because, in addition to enable the evaluation of intersections and street segments separately, it also allows the inclusion of new indicators and the redefinition of their weights.

Tables 4 and 5 presents the set of indicators considered in the evaluation of pedestrian environments for the PEQI, PSI and PEDS approaches, as well as the set of indicators proposed for PEQI adapted to medium-sized Portuguese cities (PEQI PT).

Indicators	Audit tools			
	PEQI	PSI	PEDS	PEQI PT
Number of lanes	x	x	x	x
Two-way traffic	x			x
Vehicle speed/Posted speed limit	x	x	x	x
Street traffic calming features	x		x	x
Segment intersection			x	
Crosswalks in segment		x	x	
Curb extension		x	x	

Pedestrian refuge and median		x	x	
Advance stop bar		x		
Pedestrian light signals		x	x	
Flashing yellow warning			x	
On street parking			x	
Type(s) of pedestrian facility			x	
Sidewalk on both sides		x		
Corner island		x		
Sidewalk completeness/continuity			x	
Sidewalk connectivity to other sidewalks/crosswalks			x	
Sidewalk width	x		x	x
Path/ Sidewalk coating material			x	x
Tactile pavement (guiding and/or warning)		x		
Sidewalk surface condition/maintenance	x	x	x	x
Sidewalk obstructions	x		x	x
Wayfinding aids			x	
Grade		x	x	x
Slope		x		x
Ramp		x		
Lift		x		

Table 4: Indicators considered in the different audits tools for segments analysis (1/2)

Indicators	**Audit tools**			
	PEQI	**PSI**	**PEDS**	**PEQI PT**
Presence of curb	x			x
Curb cuts		x	x	
Driveway cuts	x	x	x	x
Distance from curb			x	
Trees	x	x	x	x
Planters/gardens (public and private)	x			x
Public seating (including bus stops)	x		x	x
Presence of buffers	x	x	x	x
Land use	x		x	x
Illegal graffiti	x		x	x
Litter	x		x	x
Pedestrian-scale street lighting	x	x	x	x

Construction sites / Abando-ned/boarded up buildings	x			x
Bicycle facilities			x	
Bike rack(s) present on this street segment	x			x
Amenities (garbage cans, ben-ches, water fountain, etc...)				
Degree of enclosure			x	
Powerlines along segment			x	
Articulation of building designs			x	
Building setbacks			x	
Building height			x	
Bus stops			x	
Subjective Assessment	x		x	x

Table 5: Indicators considered in the different audits tools for segments analysis (2/2)

Indicators	Audit tools			
	PEQI	PSI	PEDS	PEQI PT
Crosswalks	x	n.a.	n.a.	x
Ladder crosswalk	x	n.a.	n.a.	x
Crosswalk scramble	x	n.a.	n.a.	x
Signal at intersection	x	n.a.	n.a.	x
Pedestrian signs	x	n.a.	n.a.	x
Stop signs	x	n.a.	n.a.	x
No Turn On Red signals/signs	x	n.a.	n.a.	
Yellow at the turning (for vehicles)		n.a.	n.a.	x
Curb cuts at pedestrian crossing	x	n.a.	n.a.	x
Intersection traffic calming features	x	n.a.	n.a.	x
Additional signs for pedestrians	x	n.a.	n.a.	x

Table 6: Indicators considered in audits tools for intersections analysis

Method

In order to adapt the original PEQI form to the Portuguese pedestrian reality, the following changes were considered:

- in the intersections form, the indicator "No turn on red signals / Signs", was changed to "Yellow at the turning (for vehicles)";

- in the street segments form, indicators "Grade", "Slope" and "Sidewalk coating material" have been added to the "Sidewalks" section. Its incorporation relates with the variety of terrain forms that can be found in Portuguese cities, which clearly influence the experience of using the built pedestrian systems;
- in the street segments form, indicators "Construction sites" and "Abandoned/boarded up buildings" were grouped into a single indicator in the section "Safety and Aesthetic Qualities";
- weight changes and attribution to indicators of the street segments form.

The indicator's weights present in the street segments form were redefined in order to increase the contribution of the "Sidewalks" section in the PEQI score. This decision was based on the assumption that a well-built pedestrian environment favours good safety conditions, including spaces shared by car and pedestrian traffic, and positively promotes the aesthetic aspects and the pedestrianization degree perceived by users.

The weight of "Traffic Calming Measures" indicator in the "Vehicle Traffic" section was increased with the option of "One or more calming measures" in the segment under analysis.

As far as inclinations are concerned, in PEQI PT, grades and slopes of the sidewalks were considered with the same weight. This is justified because "Transversal slopes" significantly influences the easiness of pedestrian's movement, and in the case of "Longitudinal grades" because in Portugal there is a significant amount of urban areas placed on non-levelled terrain, which increases its relevance and justifies its inclusion and weight .

Regarding the indicator "Sidewalk coating material", a greater weight was attributed to concrete pavement or with blocks of concrete, since this material presents better behaviour, ensuring anti-slip sidewalk conditions, maintaining surface texture even in rainy weather.

In addition to the changes presented above, other changes were made to clarify observers about witch answers best express the reality, namely in the section "Sidewalks", in which the "Permanent Obstructions" field was renamed "Permanent Obstructions / Variable sidewalk width", and the "No Obstructions" field changed to "Unobstructed /Uniform sidewalk width". PEQI forms adapted to the Portuguese medium-sized cities' reality were prepared and weights were assigned to each indicator option in the PEQI PT street segment form. The indicators weights of the PEQI PT intersection form, the score distribution and the meaning of the score were kept equal to those of the original PEQI form.

For a better understanding of all changes made, Table 7 presents the weights of the five form sections for street segment in PEQI PT proposal.

Sections	PEQI PT minimum score weight (%)	PEQI PT maximum score weight (%)
Vehicle traffic	13	17
Sidewalks	39	42
Land use	10	6
Safety and aesthetic qualities	24	16
Perceived Walkability	14	19

Table 7: Form sections weights of PEQI PT score for street segments

Application

Case study description

A case study was developed in Covilhã city, in the central region of Portugal, on the eastern slope of Serra da Estrela at an altitude around 650m. The municipality has an area of more than 550 km^2 and an estimated population of 51.797 inhabitants (2011).

The main methodological steps undertaken consisted in the study area delimitation, forms preparation, observers team training, data collection, data introduction and organization of a database for PEQI classification, insertion of all alphanumeric and geographic information in a GIS, thematic maps output and results interpretation.

With the impossibility to evaluate all parishes due to its extensive area, the study area was carried out only in the parish of Covilhã and Canhoso, where the major commercial, services and recreation areas, with a significant pedestrian flow, are located.

In total, 74 intersections and 27,4 kilometres of street segments were evaluated.

Collection and processing of data

First, in order to prepare the database for assessing the quality of the pedestrian environment, the Covilhã road network was treated in ArcGIS® software.

To implement a useful GIS project a careful planning of relevant data collection was undertaken involving the following phases:

- identify each street segment and intersection with its own unique numerical identifier code;

- determine the number of intersections and street segments to be analysed, providing enough number of forms. In the case of street segments it was decided to evaluate each side of the street separately and as such it required the double of forms;

- training the observers involved in data collecting through a theoretical exposition and practical training classes.

The data collection performed involved two teams of two elements that assessed a total of 74 intersections and the two sides of 126 street segments.

The collected data was inserted into a Microsoft Excel® spreadsheet to create the alphanumeric database and automate the PEQI PT index calculation.

Finally, the data were organized to be inserted in ArcGIS® software, being associated with the geographical component of the road network through its unique identifier defined for each intersection and street segment.

Intersections

As previously mentioned, 74 intersections were evaluated of which 41 were stop-controlled intersections, 16 roundabouts and 17 signalized intersections. Skewed intersections were not present in the study area. Most of the analysed intersections had three legs (53) and were stop-controlled (36) or signalized intersections (12).

All the data collected was entered into a previously prepared spreadsheet to receive the information and automatically calculate the value of PEQI PT score. Each PEQI PT score was then associated with its corresponding geographical component of the road network in a GIS through its unique identifier, and thematic maps were prepare.

Figure 1 shows the thematic map output with the achieved PEQI PT score for the analysed intersections.

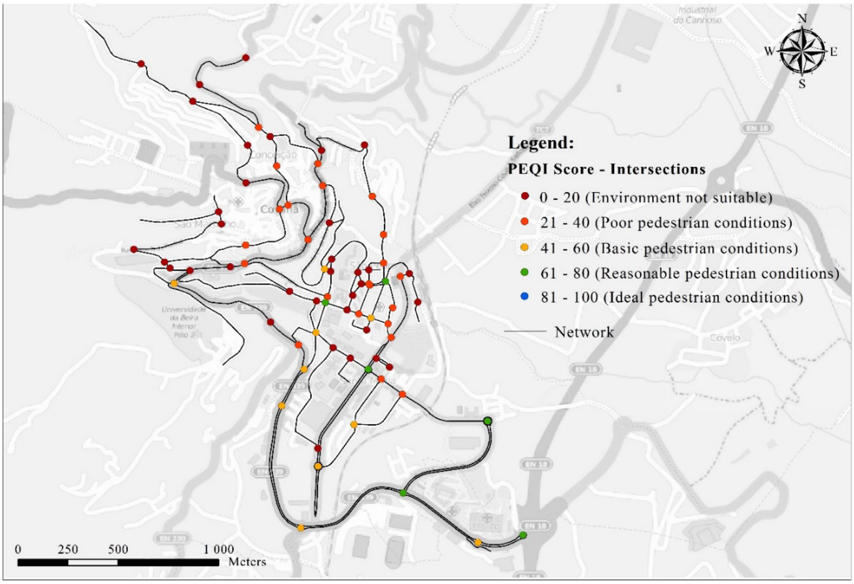


Figure 1: Case study: Intersection PEQI
PT score Source: Sousa, 2016

Street segments

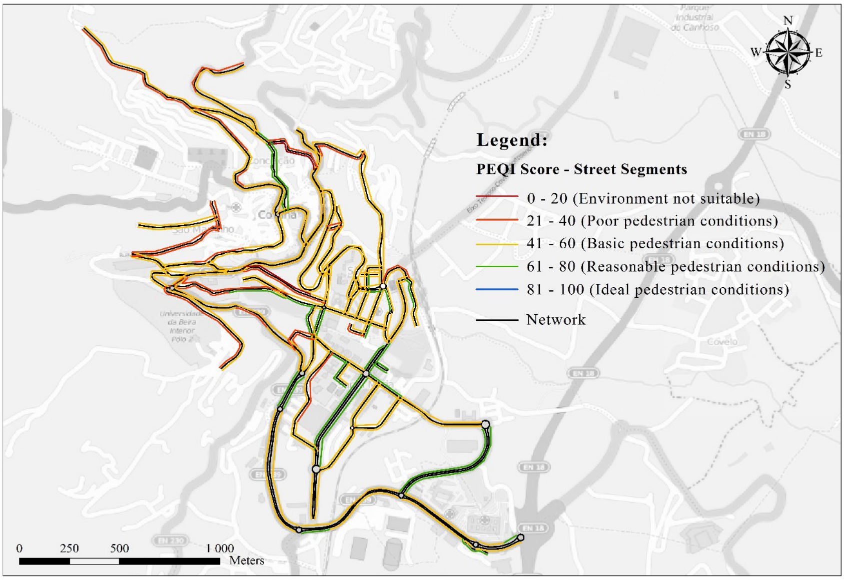


Figure 2: Case study: street segments PEQI PT score
Source: Sousa, 2016

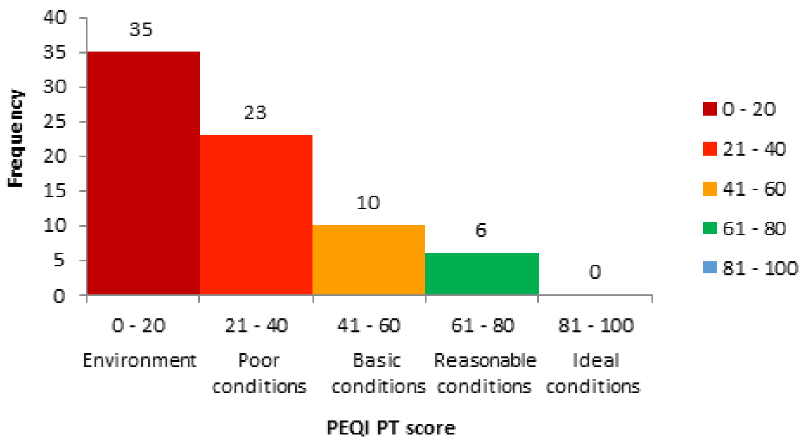
Data were collected from both sides of 126 segments (252 forms), of which 105 were segments of major collector streets (10,6 km), 65 segments of minor collector streets (9,4 km) and 82 segments of access streets (7,3 km). As for intersections, all collected data from street segments were entered into a spreadsheet prepared to receive information and automatically calculate the PEQI PT score. The score was associated with its corresponding geographical component of the road network in a GIS and thematic maps were prepared. Figure 2 shows the PEQI PT score thematic map obtained for the analysed street segments.

Results and discussion

Intersections

The maximum score obtained for intersections was in a roundabout with a score of 71. Six intersections obtained the minimum score of zero, of which three were signalized and 3 were stop-controlled intersections.

In Graphic 1 it is possible to observe the frequency distribution of the PEQI PT scores obtained for intersections, divided by the five PEQI PT classification classes.



Graphic 1: Histogram of PEQI PT classification for intersections
Source: Sousa, 2016

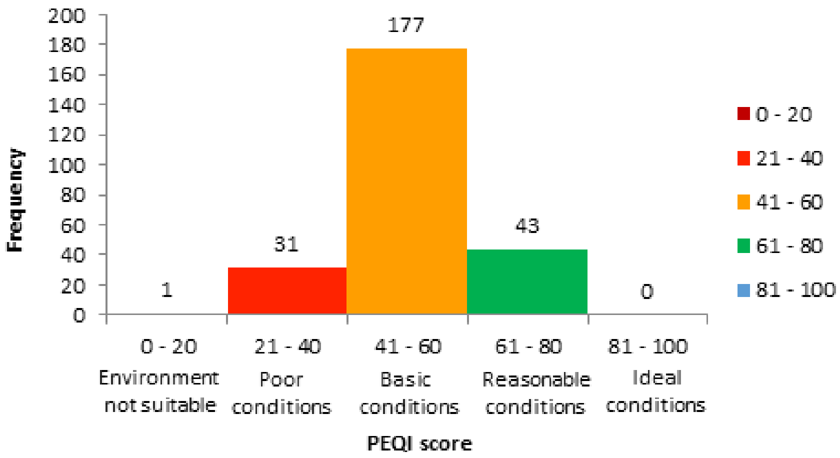
In general, it can be stated that the results obtained for intersections are not satisfactory, since approximately half of the evaluated intersections presented an environment not suitable for pedestrians with a PEQI PT score between 0 and 20.

It can also be verified that the roundabouts are those that have better classifications, since the six intersections that reveal reasonable pedestrians conditions were of this type.

Street segments

From the results obtained for street segments, the maximum score was 75 that indicate reasonable pedestrian conditions. The minimum score verified was 20.

Graphic 2 shows the frequency distribution of the PEQI PT scores obtained for street segments according to the five PEQI PT classifications.



Graphic 2: Histogram of PEQI PT classification for street segments
Source: Sousa, 2016

Observing Graphic 2, it can be concluded that most of the street segments present basic pedestrian conditions. Only one segment had the minimum classification (0-20), which indicates environment not suitable for pedestrians and no segment reached the maximum classification, with ideal pedestrian conditions.

Through the maps produced in ArcGIS® software, it was possible to verify that the intersections and street segments that obtained better PEQI

PT classifications were located in the more southern zone, that is, in the city's considered "new zone".

Limitations, challenges and recommended improvements

Several challenges were encountered during PEQI PT approach. One challenge was following the original PEQI to determine any problems or factors presents in the study area not included in the original forms. New factors were identified and incorporated during the implementation of PEQI PT: grade, slope and sidewalk coating material. With regards to grade, it is considered that its weight should be rethought and redefined supported in a more extensive literature review. If the surveys of the indicators are carried out strictly the weight may remain high, however, if it is done subjectively by the evaluator (taking into account for example the physical effort), it should decrease or be subjected to statistical treatment.

A common recommendation for all audits is the data collection in teams of at least two observers, as well as the training of all personal involved through practical and theoretical classes using protocols, video presentations and photo samples of each option available for all the indicators considered. These measures aim to ensure greater reliability in data collection and enhance observers' safety. In futures audits, it would be important to carry out night-time assessments to determine the lights conditions at night.

An important issue not sufficiently integrated in PEQI PT is how to evaluate the designs options for physical impaired pedestrians. This can be included through inquiries on impaired pedestrian's perception about the pedestrian environment quality, crossing the results with the obtained assessments in order to mitigate or even eliminate possible existing barriers.

The wider application of the PEQI PT forms will allow in the future the validation or refinement of the set of chosen indicators to evaluate the pedestrian environment and the adopted weights.

Conclusions

From the study carried out on the approaches adopted by 3 pedestrian environment audits (PEQI, PSI and PEDS) it was possible to conclude that in general pedestrian system (environment or performance) evaluation is performed separately for intersections and street segments based on their different characteristics and the pedestrian's behaviour at these places.

It can also be concluded that data collection is usually organized by topic and that some audits incorporate issues related with the observer's perception.

The most common topics are land use, pedestrian facilities and road/traffic attributes. The indicators common to the 3 audits are the number of lanes, the posted speed limit on vehicles, the sidewalk surface condition, driveway cuts, presence of trees and buffers, and pedestrian-scale street lighting.

From the ones studied, the index adopted to evaluate the quality of the pedestrian environment of Portuguese medium-sized cities was the PEQI, since it allows a greater flexibility in the incorporation of new indicators and changes in their weights, and the approach calibration for different scenarios. To calibrate the original PEQI methodology and test its applicability, a case study incorporating part of the pedestrian system of Covilhã city, especially on the areas that presented a significant pedestrian demand, was considered.

The main findings of its application to the case study indicates that, concerning the intersections, about 47% presented an environment not suitable and 31% had poor pedestrian conditions. These values are largely due to the lack of crosswalks at these sites. Only 22% presented basic or reasonable pedestrian conditions. The roundabouts were the intersections type that presented better PEQI PT classification. On the other hand, about 70% of the analysed street segments obtained basic pedestrian conditions, 12% presented poor pedestrian conditions and 17% showed reasonable pedestrian conditions.

With the application of this index it is still possible to make a study for each of the items individually. For example, it was possible to verify that about 70% of the analysed sidewalks presented some impediments and 15% significant impediments mainly due to damages caused by tree roots, which indicates a necessity to requalify them.

In conclusion, the PEQI PT score and the analysis of the information related to indicators allow to obtain an integrated view of the pedestrian environment quality of an urban area or city, the identification of the city zones with pedestrian problems and can be used to support the definition of the necessary intervention actions to improve the pedestrian environment.

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