The construction of Walkability Index in Cambé City - Paraná - Brazil

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ABSTRACT: Considering the increase of health problems related to inactivity and non-communicable diseases, such as heart diseases and obesity, many researches carry out the correlation between the built environment and physical activity. These issues relate health with urban planning studies. Walking occurs in daily activities and can be considered as a viable alternative to reduce health problems and to promote physical activity. To analyze and measure walkability it is possible to apply the Walkability Index, which was created by Frank et al. (2010a) and it systematizes four built environment variables: net residential density, retail floor area ratio, intersection density and land use mix. This article aims to describe the construction of the Walkability Index in Cambé - Paraná State - Brazil. The Walkability Index map revealed which census wards are more walkable in Cambé and showed that the instrument can be applied in different contexts. The contribution of this study refers to the development of strategies to insert walkability in the urban planning discussions and point out issues to make our cities healthier and more sustainable.

Keywords *Health; built environment; walkability; walkability index.*

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1. INTRODUCTION

Chronic noncommunicable diseases (NCD) represent a threat to health and human development in a global context and it is the main aggravation in health disorders in Brazil (Schmidt et al., 2011). These diseases constitute a serious problem in relation to public health in rich and poor countries (Malta et al., 2009). According to the World Health Organization (WHO), cardiovascular diseases, cancers, chronic respiratory diseases and diabetes are considered the main types of noncommunicable diseases. Ageing and obesity are also related to NCD and those diseases are related to behavioural issues included in people's lifestyle (Loch, 2013).

Physical inactivity is a global problem (Brownson et al., 2009) and may also increase rates of NCDs (WHO, 2003). It is still not fully understood what could be done to increase physical activity levels (Ellis et al., 2015), but there is a growing comprehension that the built environment can influence positively the physical activity frequency (Ding; Gebel, 2012; Sallis; Bauman; Pratt, 1998; Humpel et al., 2002; Sallis et al., 2012). Walkability can be a strategy to advance physical activity (Frank et al., 2012) in the built environment context or even be part of residents' daily life (Gehl, 2013). Walkable environments can provide individuals with an active lifestyle and prevent diseases such as obesity, diabetes, cardiovascular disease and types of cancer (Eyre et al., 2004).

The built environment is an important factor which can be modified to support and influence health (Frank et al., 2012; Fitzpatrick; Lagory, 2000; Handy et al., 2002). Several authors (Brownson et al., 2009; Leslie et al., 2005; Lovasi et al., 2008; Saelens; Sallis; Frank, 2003; Saelens et al., 2003; Southworth, 2005; Wood; Frank; Giles-Corti, 2010; Speck, 2012; Frank et al., 2012) relate characteristics of the built environment with their influences on walking. There is a growing interest in combining spatial objective attributes to create a composite index for application in empirical studies (Cervero; Kockelman, 1997; Lovasi et al. 2008; Frank et al., 2010b; Hino et al., 2012; Hino et al., 2013). There is a demand to understand how particular attributes of the built environment can affect human behaviour involving physical activity, but many questionings persist about how the interrelationship between them develop (Handy et al., 2002; Saelens; Sallis; Frank, 2003).

The aim of this paper is to describe the construction of the Walkability Index in Cambé - Paraná State, Brazil and to develop a spatial pattern for walkability based on the Walkability Index organized by Frank et al. (2010a). The construction of the Walkability Index in a Brazilian medium-size city contributes to understand how the built environment can influence walkability according to the analysis of objective variables and can subsidize the development of strategies to insert walkability in the urban planning issues and highlight discussions to make cities healthier and more sustainable.

The index was calculated for Cambé, whose area is 494,692 km^2 and has an estimated population of 103.822 in 2015 (IBGE, 2015). Cambé, although located in Londrina's Metropolitan Area, is a country town.

Therefore, this research presents distinct findings also in comparison with the majority of walkability indexes applied in metropolitan regions or neighbourhoods in cities of developed countries such as Australia (Mayne et al., 2013) or the United States (Frank et al., 2010a). This study also differs from others in larger cities in Latin America such as in Bogotá - Colombia (Cervero et al., 2009) or in Curitiba - Brazil (Reis et al., 2013).

2. METHODS

2.1 Index construction

The Walkability Index of Cambé was based on the index created by Frank et al. (2010a) in relation to the NQLS study and it is associated with measurements of active transportation and physical activity. The built environment can influence transportation mode choices and studies involving characteristics of community design have gained attention (Frank et al., 2010a).

The main purpose of the Walkability Index is to build up a method to analyse the built environment in order to enhance the relevance of researches about built environment and physical activity, which in a broader concern, is part of the discussion regarding health (Frank et al., 2010a).

The geographical scale was considered for the index to create a "walkability surface" in each census ward group level and the characteristics to be analysed involve net residential density, retail floor area ratio, intersection density and land use mix (Table 1).

Table 1. Variables of the Walkability Index (Frank et al., 2010a)

Variable	Description
Net residential density	The ratio of residential units to the land area established for residential use per census ward
Retail floor area ratio	The retail building floor area footprint divided by the retail land floor area footprint. This measurement indicates the relation of the area reserved for parking
Intersection density	Related to the connectivity of the street network. It is calculated by the ratio of the number of true intersections (three or more legs) to the land area of the census ward group
Land use mix	Related to the diversity of the land use types in a block group classified by: residential, retail (excluding "big boxes"), entertainment (including restaurants), office and institutional (including schools and community institutions). Values vary between 0 (single use) and 1 (completely even distribution of floor area across the five uses)

For the Walkability Index in Cambé, firstly a map of the census wards was organized according to the Brazilian Institute of Geography and Statistics (IBGE), which is the basis for setting up the index.

This study is part of an extended research, which defined census wards as samples, including only 84 census wards in Cambé (excluding 29 and 62) that were considered for the index (Figure 1).

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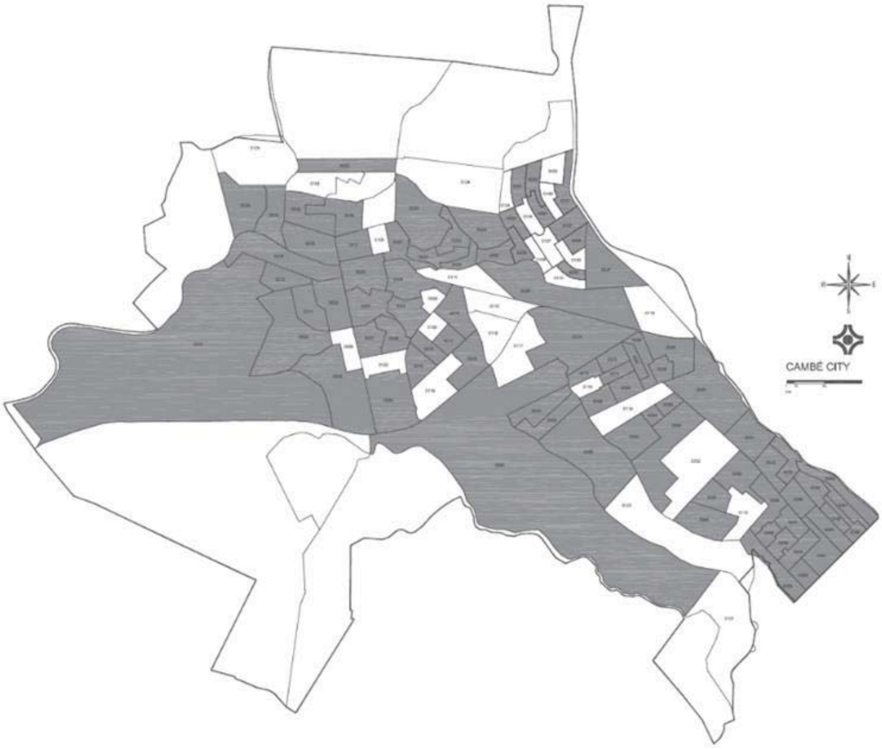

Figure 1. Census wards selected for the index. Source: Cambé City Hall, 2015; IBGE, 2015; Created by Motomura, 2015

Table 2. Criteria adopted for each variable of the Walkability Index

Variable	Criteria for the construction of the Walkability Index
Net residential density	Number of residences divided by the area of the census ward (acres). Google Street View was adopted to determine the residential use
Retail floor area ratio	In order to set the proportion in all the commercial areas or allotments, the built area and the determinant commercial use area were calculated. Google Street View was adopted to determine the commercial use
Intersection density	The types of intersections were collected in a digital map and those with 3 or more legs were selected. Intersections between two census wards were included in both. The number of intersections was divided by the area of the census ward (acres)
Land use mix	The land use of Cambé was divided into 5 categories: residential, commercial, entertainment (including restaurants, bar, cafeterias, gym, leisure, country houses), service (including offices, clinics, small industries and factories) institutional (including all city hall facilities, schools, institutions) and industry (big industries). Only the street level (ground floor) was considered because this level is associated with walking (Sung et al., 2015). Google Street View was adopted to determine all the land uses

In Brazilian cities, there are a significant number of mixed allotments, which is characterized by residential use with another one. With the purpose of constructing the Walkability Index, a spatial distribution of the mixed allotments was made (Figure 2). For

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the division of mixed allotments in order to calculate the ratio floor area and land uses both satellite images from Google Earth and Google Street View were used.

Figure 2. Distribution of mixed allotments. Source: Cambé City Hall, 2015; Goggle Street View; Created by Motomura, 2016

According to the criteria, the variables of the index were calculated, and for the land use mix the entropy formula was used:

$$-\sum k = \left(\frac{pk \times \ln pk}{\ln N} \right)$$

where k = categories of land use; p = proportion of the land use area within the census ward area; and ln = log. (Duncan et al., 2010)

All variables of the index were normalized by the "z score". The Walkability Index was calculated by the formula (Frank et al., 2010a):

Walkability = [(2 x z-score intersection density) + (z-score net residential density) + (z-score retail floor area ratio) + (z-score land use mix)]

3. RESULTS

For the construction of the index, each land use was mapped to calculate their footprint. The calculation of the index was added to Excel 2013 with the association of all variables in the formula to calculate the final walkability index for each census ward based on the "z score" of each variable: intersection density, net residential density, land use mix, retail floor area ratio (Table 3).

Table 3. Calculation of Walkability Index

Census Ward	Intersection density		Net residencial density		Retail floor area ratio		Land use mix		Walkability index
	Raw score	z Score	Raw score	z Score	Raw score	z Score	Raw score	z Score	
1	0,436	-0,020	10,441	-1,053	0,680	-0,004	0,355	-0,077	-1,170
2	0,454	0,072	15,827	0,085	1,020	1,168	0,533	1,371	2,770
3	0,362	-0,384	13,687	-0,367	0,840	0,565	0,570	1,673	1,100
4	0,842	1,980	11,847	-0,756	0,700	0,070	0,455	0,740	4,010
5	0,571	0,643	12,759	-0,563	0,840	0,565	0,224	-1,143	0,150

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It was observed that Cambé presents from medium to high intersection density in well-established areas with the exception of the industrial districts; the predominance of residential use; four axes of commercial uses and a range of districts with mixed land use.

Using the ArcGIS 10.3.1 free version, the map of the Walkability Index was constructed and was separated in five groups: High, Medium, Low and in-between (Figure 3).

WALKABILITY INDEX - CAMBÉ CITY, PARANÁ STATE, BRAZIL

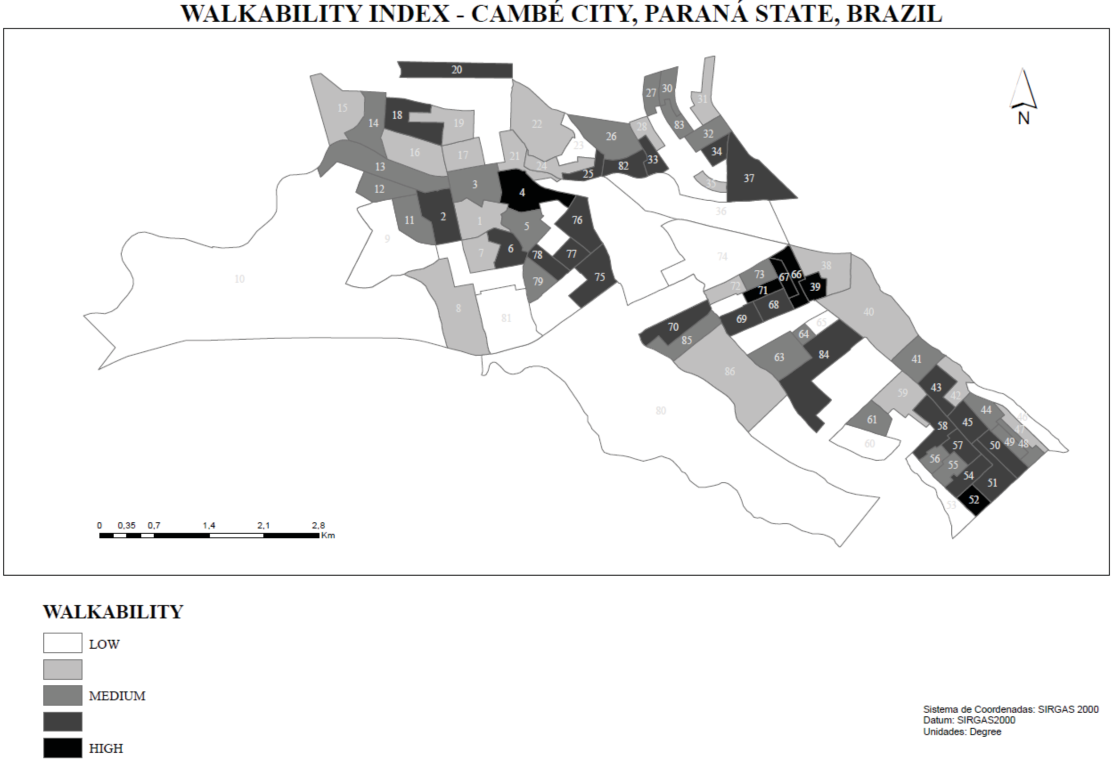

Figure 3. Walkability Index map. Source: IBGE, 2015; Created by Motomura, 2016

4. DISCUSSION

The map of Walkability Index (Figure 3) pointed census wards 4, 39, 66, 67, 71 and 52 as the most walkable in Cambé. These census wards define three groups with high walkability. They are situated in distinct areas far from each other: downtown and in the outskirts.

This evidence seems to be related to the mixed land use, which demonstrates that the highest walkable blocks are located near commercial and service concentration areas. These areas provide destinations that are within walking distance instead of the need to use other means of transportation.

Furthermore, these census wards present a higher number of net residential density in comparison to those with high commercial concentration, which infers that a higher number of residents can provide more pedestrian activity. Furthermore, the same census wards presented higher intersection density, suggesting a positive relation between connectivity and physical activity, suggesting that highly integrated street segments are easily accessible and are considered to have higher pedestrian activities Koohsari et al. (2014)

Recently, walkability indexes have been applied in cities in developed countries or in larger cities in Latin America, where an advanced database is settled considering their urban planning development. For this research, strategies for the creation of a Walkability Index database were necessary: in most cases in Brazil, land uses are organized into mixed allotments, so it was necessary to determine those mixed allotments and divide them by land uses; although images from Google Earth and Google Street View do not provide a fine resolution or are not updated, it was required to adapt these instruments for the research purpose. Notwithstanding, these strategies seem to be an alternative to create the Walkability Index in small and medium-size cities.

5. CONCLUSION

This research presents the construction process of the Walkability Index in Cambé. The result and pattern of this achievement is the basis for further correlational analysis concerning evidences of the built environment as a support to improve physical activity as well as to contribute to the understanding with socioeconomical issues.

Therefore, the index synthesizes only four main variables considering the built environment and walkability urban features: intersection density, net residential density, mixed land use and retail floor area ratio. In addition, considering that it was possible to apply the Walkability Index in Cambé, even with no previous database, it is suggested that this instrument can be adapted to distinct cities.

The findings of this study may ensure public policies in order to propose guidelines to insert walkability in the urban planning process, even though there is still a disparity between academic research application and practical procedures. Moreover, it contributes to a better understanding on the influence of the built environment on healthier behaviors, which are issues related to sustainable urban planning.

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