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HOMOGENEOUS ZONES FOR URBAN MOBILITY PLANNING: CASE STUDY OF BALNEÁRIO CAMBORIÚ, BRAZIL

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Abstract
Developing countries are facing several urban issues about mobility, mainly due to the increase in the number of cars that causes several negative impacts, reducing the quality of life of the population. Among the issues that influence this situation is a deficit urban planning, with the absence or fragmentation of monitoring, production and analysis of transport data, impairing the development of studies for decision making that favors an efficient mobility system and more Sustainable development. For this, the purpose of the work was to determine a methodology for proposing homogeneous traffic zones to subsidize and optimize data collection of vehicle flow and understanding the generation and attraction of trips. The research was validated in a case study in a Brazilian municipality, where statistical and geographic methods were used to define homogeneous regions, based on socioeconomic data from census tracts. It was considered the indicators of demographic density, employment and economic level and per capita household income. The analysis resulted in the definition of five zones with homogeneous socioeconomic characteristics varying from areas with lower demographic, employment and income densities, to areas with high demographic density, employment and income, which allow inferring adequately about the intensity of traffic in each zone.
Keywords: Urban mobility, Homogeneous traffic zones, Traffic planning

1. INTRODUCTION

Developing countries are facing several urban issues resulting from lack of planning. In transport issue, there is in course a process of increase in the number of private vehicles the main mode of transport. etc. Associated with a precarious transport infrastructure, a series of negative social, economic and environmental effects are underway, such as congestion, public health problems, air pollution, noise, etc.

Among the challenge of these countries is the data and information generation to subsidy the urban planning. In Brazil this process is not different, where the large majority of the cities do not have urban mobility plans, as determined by the National Policy on Urban Mobility (Brasil, 2012), besides not having enough database to manage urban mobility effective and efficiently as pointed by Filho (2012), Pepe *et al* (2010) and Pontes (2010).

The acquisition of traffic data represents one of the major frailty for transportation planning in municipalities in Brazil. Counts of vehicle flows and surveys of origin/destination are difficult to obtain and there is no data collection system at strategic points in the city, only occasional studies or initiatives in large cities. This make difficult to carry out accurate projections considering more integrated and larger-scale approaches, such as interregional and metropolitan areas.

Among the preliminary approaches to traffic studies is the definition of zones, largely used for aggregated geographic representations that represent locations that generate and attract trips and a generalized network to represent the transportation system that could affect the results from travel demand analysis (Miller, 1999).

Urban transportation planning traffic analysis zones are used to represent urban trip origin and destination instead of the actual trip ends. That zoning is important, because data collection at the household and employment unit level is largely unfeasible, especially in cities that doesn´t has implemented database (You, *et al,* 1998).

Ideally, a traffic zones should be homogeneous in population, socioeconomic, and land-use characteristics (Chang *et al*, 2002 e Cardoso, 2010). Thus, the traffic zones should be defined primarily by these characteristics according to geographical location.

The importance of these zones for planning is increased when bounded by affinity to form homogeneous zones. Search results of Karlaftis and Tarko (1998) and Abdel-Aty *et al*. (2011) shows that models developed for homogeneous zones are more efficient than others that do not used it. If not accounted for, heterogeneity may lead to biased coefficient estimates for the models.

Ortúzar and Willumsen (2001) cite the following factors that influence the production of trips: income, car ownership, household structure, family size, land value, residential density, accessibility. For Cardoso (2011) the priority factors are the number of jobs offered, the level of commercial activity and the number of school enrollments.

Frank and Pivo (1994) studied the relationships between socioeconomic variables and transport flow. The parameters employment density, population density, land-use mix, and passenger car usage were found to be consistently negative for both work and shopping trips. The relationships between employment density, population density, land-use mix, and transit and walking were consistently positive for both work trips and shopping trips. It should be regarded, however, that the study was conducted for downtown Seattle, which has a well-structured transit network and good walkability rates, and these findings should be carefully incorporated into developing countries.

O´Neil (1991) and Hutchinson (1979) points out guidelines for delineating traffic zones, including: the boundaries should preferably be compatible with census tracts; geographical and physical obstacles can be used; main roads do not always constitute reasonable boundaries of areas, as land use types on either side of the street are generally similar, which may place them within the same area. Sanches (1997) complements that in the grouping of census tracts, it is attempted to make each resulting zone as compact as possible (similar transversal dimension).

To physically delimit the zones, the criterions generally adopted can be summarized in: homogeneity with respect to the socioeconomic characteristics; compactness of traffic zones shapes; respect of administrative limits as census sections, municipal borders, etc.; respect of physical geographic separators placed on territory as railways, rivers etc.; and exclusiveness (Binetti and Ciani, 2009).

Oppenheim (1995) asserts that no formal methods for defining the zones system exist, and the characteristics of these zones must be decided on empirical bases in every specific situation. The final choice, in general, has decisive effects on the predictions developed, and depends on the available resources in terms of data, computational resources and levels of detail required.

However, not all of these conditions may be incorporated into the analysis, due to the limitations noted above. Thus, in the absence of data on travel flows, one way of identifying homogeneous urban regions would be through data on the supply of transport infrastructure, or more specifically, through the use of indicators that represent this supply (Manzato and Silva, 2006).

Studies have used demographic density with alternative criterion over other measures, in the absence of consistent and reliable data describing individual's displacements to the definition of homogeneous urban zones, as the researches of Manzato and Silva (2006) and Magalhaes *et al* (2009). The adoption of population density as a substitute for what would be a more recommended indicator (travel flow) does not, however, consider the possibility of adopting a proxy variable to describe travel flows between municipalities (Manzato and Silva, 2006).

In addition to aggregation techniques based on socioeconomic data analysis, design has to incorporate methods to deal with spatial aspects of the defined basic areas. Integrating techniques combining Geographic Information System (GIS) and statistical methods could be a better approach to satisfactory determine homogeneous traffic zones (You, *et al*, 1998). The geographic distribution of census data is important in order to capture spatial dependence and heterogeneity in travel and location models (Miller, 1999 and Miller; Shaw, 2015).

Between the methods to zonal aggregation usually statistical approach are used, such as hierarchical methods. However, statistical approaches itself has limitations, that cannot ensure the optimality of zonal aggregation and generates a difficulty in considering the contiguity constraint which is a necessary requirement in the process (You, *et al,* 1998). Geographic Information Systems (GIS) has been utilized to analyze disaggregate socioeconomic and land-use data, to form optimal transportation analysis zones (O´Neil, 1991), that combined to statistics methods to determinate homogeneous traffic zones generate a better result (You, *et al*, 1998).

According to Malhotra (2006) cluster analysis is a technique used to classify objects into relatively homogeneous groups, where objects in each group tend to be similar to each other but different from objects in other groupings. Similarity measures are calculated for all pairs of objects, making it possible to compare any object with another.

The distance measures represent the similarity, which is represented by the proximity between the observations along the variables (Seidel *et al*, 2008).

Among the most used methods for this analysis, being highlighted k-means cluster, partition model that provides more precise indications about the number of conglomerates to be formed, much used when having many objects to group. The most commonly used criterion of homogeneity within the group and heterogeneity between groups is the sum of residual squares based on analysis of variance. The smaller the value, the more homogeneous the elements within each group, and better the partition (Bussab *et al*, 1990).

Therefore, considering the need for the definition of homogeneous zones to subsidy the management of Brazilian cities and to optimization of collection and treatment of traffic data, the purpose of the research was to determine a methodology for the proposition of homogeneous traffic zones, having by case study the municipality of Balneário Camboriú. The study municipality is located on the south coast of Brazil, with a population of about 131,000 inhabitants (IBGE, 2016), but it is estimated that it receives about 3 million tourists during the year (Santur, 2008), especially in summer, which potentiates the problems related to congestion and urban mobility.

2. METHODOLOGY

In order to satisfy delimitation criteria of homogeneous zones, previously mentioned, it was necessary adapted a socioeconomic criteria related to traffic flows, taking into account that previous data about demand was not available.

As pointed out by the literature review, important indicators to characterize phenomena that generate travel and commuting trips are related to population concentration, concentration of economic activities and people's economic income. To this, traffic flow indicator was replaced to indirect measures as demographic density and per capita household income.

In the developed of the study, the geographical desegregation was made based in census tracts defined by the national institute of statistical (Instituto Nacional de Geografia e Estatística - IBGE), where it was defined that the edges of the homogeneous units correspond to edges of census tracts.

The indicators of demographic density and per capita household income were obtained based on data from the census conducted in 2010 by IBGE (2010). It was necessary to make corrections in the census shapes, where some sectors, because of their very small size, generated distortions in the values of demographic density, and were usually inserted within other sectors. In this way, sectors with areas smaller than 10,000 square meters were incorporated by sectors that circumscribed them.

It was also sought to include data on the geographical distribution of economic activities and jobs. These data were obtained based on the number of commercial, industrial or institutional activities present in each census sector, generating a density of economic activities. As the city's economy is heavily based on the tertiary sector of service provision and tourism, secondary sector (industry) were not distinguished of the tertiary sector. Still, the municipality has no rural area, and so the primary sector was disregarded.

Both obtained data were carried out in the Geographic Information System, where demographic density and income were extracted from the geographic database of IBGE. The mapping of economic activities was done considering the Open Street Maps (OSM) database. This base, however, was incomplete, requiring manual completions, based on the use of Google Earth, which allowed the inclusion of points not considered, with the reference year of 2016.

With the tabulated data, statistical treatments were carried out to form homogeneous groups, done through cluster analysis k-means. Before applying k-means method, it was performed a hierarchical grouping by means of Ward method, which, according to Seidel *et al* (2008) defines more effectively the number of groups to be used, while the k-means method better classifies the groups within the groupings. All analyzes were done by Portal Action software, as an extension of Excel.

After defining these groups, a comparison was made between the zones, comparing the variables used, and considering basic statistical measures, such as mean and standard deviation. This allowed to classify each zone according to its urban and socioeconomic characteristics within the context of the studied municipality.

3. RESULTS

Applying the statistics methods it was identified five main groups in the row of selected indicators, denominated: z1, z2 z3, z4 e z5 (**Error! Not a valid bookmark self-reference.** and Figure 1). The sectors considered have weighted characteristics of the three variables considered, varying geographically from regions with low demographic density, low level of economic activities and low income, to regions with high population density, economic activities and higher incomes, where it is possible to relate with higher or lower flows of vehicles.

TABLE 1 – DESCRIPTION OF THE HOMOGENEOUS ZONES DEFINED TO BALNEÁRIO CAMBORIÚ, BRAZIL

Zone	Cluster description	Number of census tracts	Total Area of the zone (km²)	Travel generation potential	Mean / Standard deviation		
					Economic activity (establishments/km²)	Demographic density (inhab./km²)	Income (% household with <1 MS*)
Z1	Low demographic density, income and mix-use.	39	31,2	Low	0,6/ 10,5	5.834,5/ 5486,9	0,40/ 0,09
Z2	Low demographic density and income and intermediate mix-use.	33	9,124	Low	6,5/ 17,1	6.233,9/ 3.869,6	0,22/ 0,08
Z3	Intermediate demographic density and mix-used and high income.	54	3,924	Intermediate	6,1/ 9,5	8.159,5/ 3.945,6	0,13/ 0,05
Z4	High demographic density, income and mix-use.	46	1,28	High	8,9/ 6,2	12.896,2/ 2.189,2	0,12/ 0,06
Z5	Very high demographic density, income and mix-use.	37	0,716	Very High	19,0/ 11,5	21.998,8/ 3.716,4	0,14/ 0,09

* MS: Minimum salary on the base year of census (2010): US$156.

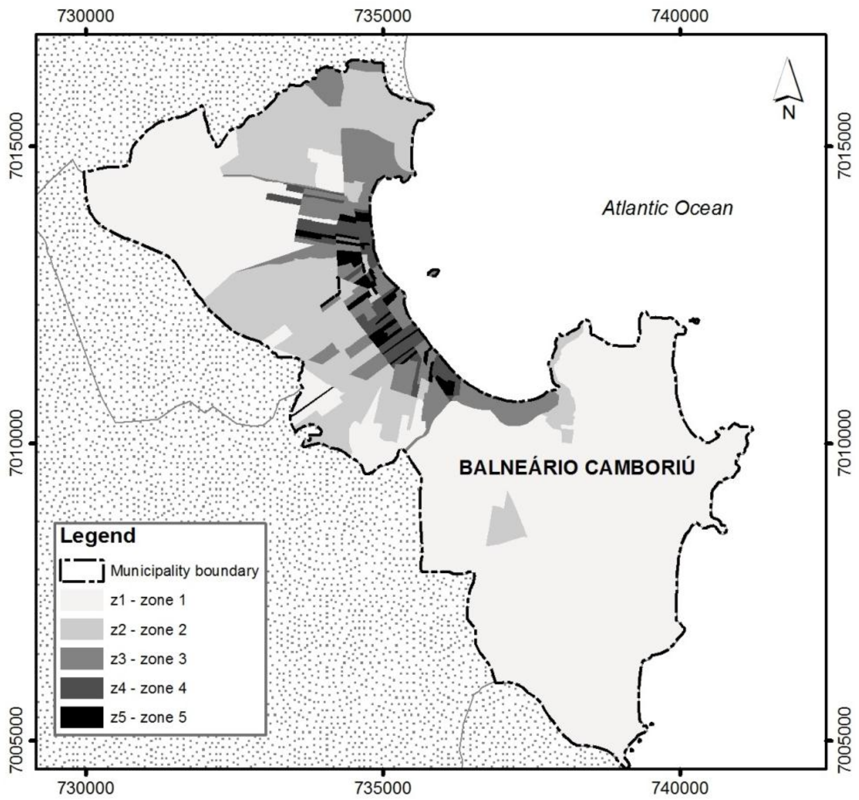

FIGURE 1 - HOMOGENEAN TRAFFIC ZONES IN BALNEÁRIO CAMBORIÚ, BRAZIL

4. DISCUSSIONS

The geographic distribution of the zones showed trends in the coastal-inland direction. The coastal region has a greater potential of attraction and generation of trips due to the tourist influence of the region, containing a high demographic density due to a high level of verticalization of the buildings, high density of economic activities and greater concentration of families with high income.

The definition of the zones made it clear which regions of the city where transport flows are most intense and consequently the problems of mobility are more evident, such as congestion. These areas coincide with the highest concentrations of commercial activities and a high population density.

The results achieved will support more specific transport approaches in the city, where it will be possible to allocate counting points and cover any data gaps, since flow monitoring points are limited due to institutional priority issues and resource limitations.

It is also worth noting that the methodology has a good flexibility and is important so that, in the future, it may be integrated other variables, creating an opportunity to improve the model of definition of the zones, especially incorporating measurements of traffic flow.

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5. CONCLUSIONS

The technical approach to sustainable urban mobility issues in developing countries is urgent given the socio-economic and environmental implications of the current urban transport model. In addition, there are major weaknesses in the planning process, mainly due to the lack of data and technical studies to permeate in-depth analyzes and strategies of action or viability.

The objective of the research was reached, being possible to determine homogeneous zones with potential of generation and attraction of trips that will subsidize future studies of traffic and urban mobility in the city. In this sense, the method sought to advance the theme, using scientific criteria applied within the limitations of available data. Even if important advances were made such as the compatibility of census data, some of the ideal conditions for the elaboration of traffic zones were impracticable, for example, the varied form of census tracts developed by IBGE should be treated with caution not to cause great distortions to the study.

However, the most important conditions have been incorporated, but there may still be small distortions that can affect a result, and it is recommended that these zones be complemented later with traffic flow data, so that the accuracy of the projections could be improved.

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