Spatial Analysis and Statistics of Pedestrian Injuries in Curitiba through a Grid Database

Cassiano Bastos Moroz[1], Jorge Tiago Bastos[1]

[1]Departamento de Transportes – Universidade Federal do Parana (UFPR)
Postal Code 80050-540 – Curitiba – PR – Brazil

cassianomoroz@gmail.com, jtbastos@ufpr.br

Abstract. *This study addresses the pedestrian exposure to traffic accidents in the Municipality of Curitiba, in Brazil, by spatially analyzing fatal traffic accidents during the period 2010-2016. The proposed methodology englobes the application of GIS through the implementation of a grid database that correlates, on a macroscale, traffic accidents intensity – calculated by Kernel Density Estimator – with spatial factors of the built environment. Although the statistical analysis has not been concluded, preliminary results demonstrate a relation between population density, monthly income and traffic injuries.*

1. Introduction

Since the 1980s, in the midst of globalization, Brazilian urban areas have been experiencing the increasing advance of motorized vehicles with the encouragement of the city's "highway" configuration. Simultaneously, there was a stagnation of urban public transport, driven by the fragile economic growth, portrayed in the form of informal vans and motorcycle taxis [Maricato 2008]. Only two decades later there were efforts to create an effective legislation to promote sustainable urban mobility through the valorization of non-motorized modes of transportation, including pedestrian and cyclists, and the increase of an efficient and affordable public transport system. Among these legislations, stand out the Law nº 10.257 from July 10th, 2001, and the Law nº 12.587 from January 3rd, 2012.

In this context, it is essential to highlight the participation of pedestrians in Brazilian urban life. According to the report published by the Brazilian National Public Transport Agency [ANTP 2016], in 2014, non-motorized transportation corresponded to 40% of total urban displacements in Brazil, 36% of which refers to pedestrians and 4% to cyclists. Although the representativeness of this transport is higher in small municipalities, the use of non-motorized transportation is still considerable in large Brazilian urban centers with populations of more than 1 million inhabitants, covering 36.3% of total displacements [ANTP 2016].

Despite their expressive participation in urban life, pedestrians are highly vulnerable to traffic accidents. According to the Datasus Mortality Information System (SIM), pedestrians constituted 22.83% of total deaths caused by traffic accidents in Brazil in 2015. The numbers are even worst when observing that traffic accidents in 2015 were among the main causes of death in the country, with a mortality rate of 18.9 per 100,000 inhabitants [Datasus 2015]. For all these reasons, there are lots of aspects to be improved in the road infrastructure of Brazilian urban areas.

Considering the severity of this scenario, this study aims to map the exposure of pedestrians to traffic accidents within the Municipality of Curitiba, in Brazil, through an empirical analysis. Therefore, the methodology income is based on previous fatal traffic accidents registered within Curitiba during the period 2010-2016.

2. Literature Review

Several studies related to road safety use the Geographic Information Sciences to spatially analyze traffic accidents in urban areas. Anderson (2009) identified hotspots of traffic accidents in Greater London, in the United Kingdom, by using the Kernel Density Estimator (KDE) and a 5-year database from 1999 until 2003.

Similarly, Schuurman et al. (2009) studied the hotspots of traffic accidents involving pedestrians in Vancouver, Canada, also by adopting the KDE. From the defined hotspots, they had verified a range of features of the built environment, such as road infrastructure and land use, thus identifying their influence on the intensity of those accidents.

In this context, Druck et al. (2004) emphasize the importance of a density analysis to verify systematic patterns of a selected spatial data. According to them, the identification of patterns, such as hotspots, implies that individual occurrences, when in proximity, may be associated with common causes, that they are spatially dependent [Anderson 2009]. Therefore, it is noticeable that the spatial analysis of traffic accidents is an important tool to understand the effects caused by different urban features, thus providing valuable outcomes for a safer urban planning and design.

3. Methodology

3.1. Determination of Traffic Accident Hotspots

For the empirical density analysis, it was adopted a database of traffic accidents provided by the Life in Transit Project (in Portuguese, *Projeto Vida no Trânsito*) from the Ministry of Health of the Brazilian Government. This database englobes a georeferenced group of fatal traffic accidents occurred during the period 2010-2016 in the Municipality of Curitiba. In the context of this study, there were analyzed uniquely the occurrences involving pedestrians.

First, in order to identify the hotspots of the analyzed traffic accidents, their spatial distribution was determined on GIS software by using the Kernel Density Estimator (KDE). This methodology is widely adopted in a range of studies, such as those described in the previous section [Anderson 2009; Schuurman et al. 2009]. The KDE method uses two inputs in order to conduct the analysis: the spatial data, as a group of georeferenced points – in this study, it refers to the traffic accidents – and the bandwidth.

It is important to highlight that several authors [Anderson 2009; Schuurman et al. 2009; Hashimoto et al. 2016] comment on the subjectivity in the definition of the bandwidth for the accurate analysis of traffic accidents. It can be observed that its variation can lead to significant changes in results, as pointed out by Druck et al. (2004). While a low value can create an irregular surface, a high bandwidth should make it softened. On this study, a 200-meter bandwidth was defined based on similar analysis carried out in previous publications.

Finally, after applying the KDE, a 1-meter spatial resolution raster file was created as an output, highlighting the hotspots of fatal vehicle-pedestrian traffic accidents. This raster file is represented in Section 4 of this article.

3.2. Spatial Analysis Grid

In order to allow the correct association of the spatial factors to the corresponding accident intensities, a 300-meter-spatial-resolution grid, in shapefile format, was created covering the whole area of the Municipality of Curitiba so that different values could be attributed to each pixel.

The spatial resolution was determined seeking a balance between low values, which would prevent the effective analysis of the characteristics of the road system, such as the number of intersections and road density, and high values, which would result in a loss of accuracy of punctual data as is the case of the socioeconomic index.

After creating the grid, a filtering process was conduct in order to eliminate the pixels located over areas that are not urbanized. This process was conducted taking into consideration the 2015 Zoning Plan of the Municipality of Curitiba, made available by the Research and Planning Institute of Curitiba (IPPUC). In this way, all pixels located in Environmental Protection Areas and industrial, service and military zones were deleted. Figure 1 schematically shows the filtering process, presenting the resulting grid.

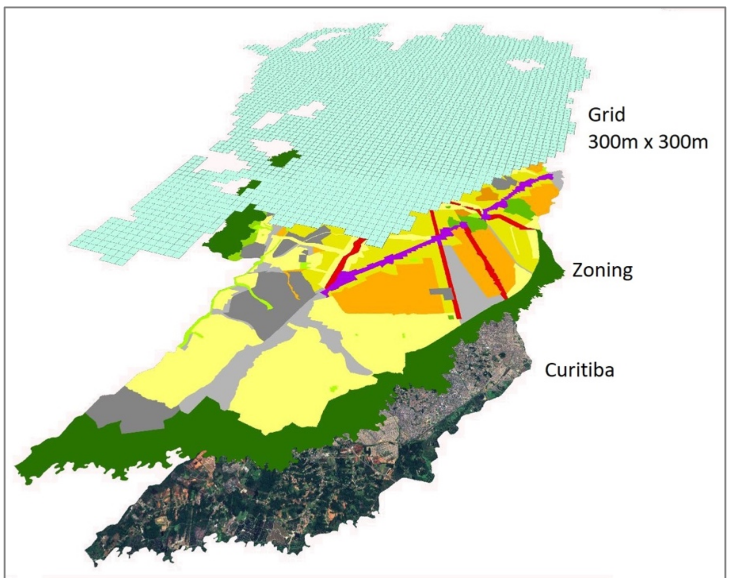

Figure 1. Spatial analysis 300-meter-resolution grid

3.3. Determination of the Independent and Dependent Variables

To effectively map pedestrian vulnerability to traffic accidents in the Municipality of Curitiba, it is crucial to determine which features of the built environment are relevant for the analysis. First, the factors related to the configuration of the road system were analyzed based on the road system shapefile of the Municipality of Curitiba, made available by IPPUC. This file assigns a hierarchical classification to all the roads within the city, associating a higher hierarchy (number 5) to highways and a lower hierarchy (number 1) to local roads.

By taking into consideration this shapefile, it was determined the road density, the road maximum hierarchy and the difference between maximum and minimum hierarchies within each pixel. The road density was calculated as the ratio between total road length within the pixel and its area. In its turn, the maximum hierarchy was extracted using spatial analysis tools and refers to the highest road hierarchy registered in the analyzed pixel. In this way, regions crossed by highways present higher values in relation to regions crossed only by local roads. Finally, the difference between maximum and minimum hierarchies refers to the subtraction between the highest and the lowest values recorded in a pixel, thus indicating a probability of intersections of roads from different hierarchies, which may culminate in a higher susceptibility to traffic accidents.

In addition to the characteristics of the road system, the per capita income and the population density were calculated for each pixel. Both variables were obtained through the census tracts of the 2010 Census, provided by the Brazilian Institute of Geography and Statistics (IBGE). The conversion of these values from the shapefile of census tracts to the 300-meter-resolution grid was performed through the following methodology:

a. the census tracts – already containing the values associated with the variables – were converted into a raster file with a spatial resolution of 1 meter;
b. the spatial statistics tool was used to calculate the mean of all 1-meter-resolution pixels inserted in the 300-meter-resolution pixel from the grid. Thus, for each grid pixel, the average of 90,000 values for population density and per capita income was calculated and attributed to it.

Therefore, by following the methodology described above, five features of the built environment were analyzed, calculated and attributed to the grid. Figure 2 shows schematically these variables, already converted to the grid format.

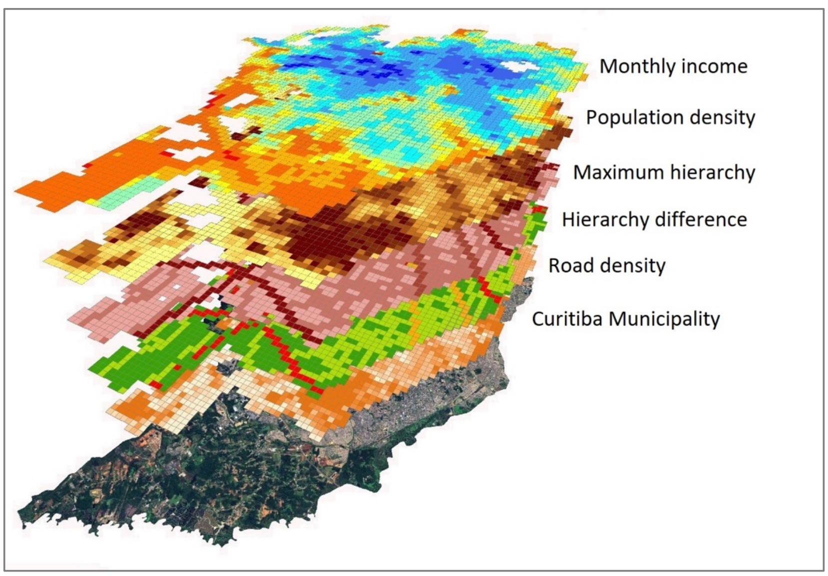

Figure 2. Independent variables attributed to the grid

Finally, the intensity of fatal pedestrian-vehicle traffic accidents – previously obtained by KDE – was also attributed to the grid. The methodology for this assignment consisted of the following steps:

a. initially, we tried to understand the theory of the KDE. This method distributes the unit value of the accident in a circular area, of radius pre-established by the bandwidth, where all the pixels generated around an accident, when summed, produce the unit value of that accident;
b. therefore, to attribute the value corresponding to the intensity of traffic accidents to each 300-meter-resolution pixel from the grid, the raster file of hotspots was analyzed and all 1-meter-resolution pixels within the grid were summed. This means that a total of 90,000 values have been summed to generate a result of the intensity of traffic accidents for each pixel from the grid.

4. Results and Discussion

For this study, a hotspot analysis was conducted by applying the Kernel Density Estimator and based on the traffic accidents database from the Municipality of Curitiba, as presented in Figure 3. Even though the statistical analyzes that relate spatial variables to the intensity of accidents in the region have not been concluded, it is already possible to visually identify spatial patterns relevant to the research.

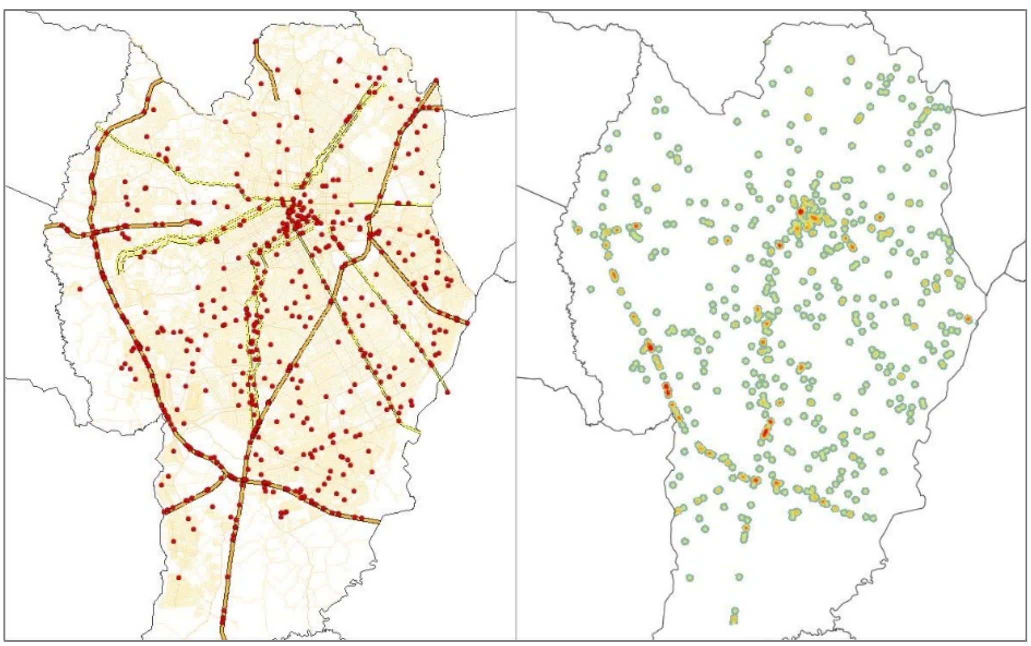

Figure 3. Pedestrian injuries database (in red, left) and hotspots obtained through Kernel Density Estimator (right)

There is a high concentration of fatal traffic accidents involving pedestrians in the central region of Curitiba, which has a higher population density. Additionally, hotspots (shown in red in the figure on the right) are also identified along highways and structuring streets, especially in the south, which is a region characterized by a lower per capita income when compared to the center and north of the city.

In this way, it is believed that through statistical analysis, especially a multiple linear regression associating the dependent variable (intensity of traffic accidents) with the independent variables (features of the built environment), it will be possible to map the exposure of pedestrians to traffic accidents within Curitiba in the next stages of this study.

5. Conclusion

This article seeks to understand the influence of the features of the built environment on the intensity of vehicle-pedestrian traffic accidents within Curitiba. As a database for the study, a georeferenced group of traffic accidents registered during the period 2010-2016 were spatially analyzed through KDE. Finally, the identified hotspots were associated with spatial factors of the urban area, including the characteristics of the road system, the per capita income and the population density.

In the next steps, the study aims to use statistical analysis of the attributes obtained through this methodology in order to map the pedestrian exposure to traffic accidents within Curitiba. This analysis includes the use of multiple linear regression, associating the intensity of fatal vehicle-pedestrian traffic accidents (dependent variable) with the features of the built environment (independent variables).

6. Acknowledgement

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7. References

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