

# Spatial analysis of deaths due to traffic accidents, before and after the Brazilian Drinking and Driving Law, in micro-regions of the state of São Paulo, Brazil

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## SUMMARY

**Objective:** To identify special micro-region clusters according to mortality rates resulting from traffic accident in the state of São Paulo, Brazil, during the period of one year before and one year after the enactment of the Brazilian Drinking and Driving Law. **Methods:** Ecological and exploratory study in the period of 2007 and 2009 in 63 micro-regions of the state of São Paulo. Geoprocessing tools were used with data from DATASUS (Database of the Brazilian Unified Health System), in order to analyze deaths resulting from traffic accidents at rates per 100,000 inhabitants and to build choropleth maps. New statistics were obtained by subtracting the 2009 rate from the 2007 rate, and regions with improvement or deterioration were observed. **Results:** In 2007, there were 5,204 deaths, averaging 83 deaths/micro-region, and ranging from 1 to 1,440. In 2009, there were 5,065 deaths, averaging 80 deaths/micro-region, and ranging from 1 to 1453. In 2007, the Moran's coefficient was  $I = 0.09$  ( $p = 0.04$ ), with positive spatial correlation; in 2009, the coefficient was  $I = 0.04$  ( $p = 0.16$ ), with no correlation. The difference between rates was  $I = 0.23$  ( $p = 0.007$ ), indicating spatial association. In 2007, Presidente Prudente, Rio Claro, Campinas, Bragança Paulista, Osasco, and São Paulo presented high mortality rates. Of these regions, only Osasco did not stand out in 2009. Ribeirão Preto, Ourinhos, and Avaré deteriorated in 2009. The difference between the 2009 and 2007 rates showed that Amparo, Bragança Paulista, and Campinas improved, and that Presidente Prudente and Ourinhos deteriorated. **Conclusion:** It was possible to identify the places with higher mortality rates, pointing out locations where enforcement actions should be reviewed.

**Keywords:** Geographic information system; traffic accidents; alcohol abuse.

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## INTRODUCTION

Traffic accidents are a serious public health problem<sup>1-4</sup>, representing one of the set of modern epidemics that ravage several countries around the world. In Brazil, external causes occupy the third place in the rank of causes of death, and traffic accidents are the second in frequency among them<sup>5,6</sup>. Victims that do not die have high chances of remaining with deficiencies that will affect not only their personal, but also their family life<sup>7</sup>, with a high social cost.

A study performed in 2008 in Brazil by the Brazilian Association of Traffic Medicine (Associação Brasileira de Medicina do Tráfego), showed total spending on patients admitted to the Unified Health System (Sistema Único de Saúde – SUS) as a result of traffic accidents of almost R\$ 100 million; approximately 4,000 victims died<sup>8</sup>.

These expenditures result from expenses with rescue, hospital care, rehabilitation, and years of potential life lost (YPLL).

This last item deserves great attention, as accidents especially affect young men and women. This group is the most engaged in work activities, the age group that influences the economy the most, and – should they stop working due to accident sequelae – that will trigger potential social security expenses.

When discussing potential human factors that cause traffic accidents, alcohol has been cited as one of the main factors, studied in several countries and corroborated by many studies<sup>5,6,9-16</sup>. Under the influence of alcohol, accidents are more serious and the mortality rate is higher. In Brazil, alcoholic beverages are pointed out as one of the main factors responsible for accidents. There are several factors that may lead to an increase in the consumption of alcoholic beverages by the population<sup>17</sup>, including easy availability, low cost, and advertisement.

Until early June, 2008, the permitted blood alcohol level in Brazil was 0.6 g/L. The Brazilian Drinking and Driving Law<sup>18</sup> changed this limit to 0.2 dg/L or the equivalent to 0.1 mg of alcohol per liter of exhaled air into the ethylometer, popularly known as “breathalyzer”. The risk of getting involved in fatal accidents<sup>19</sup> for drivers with blood alcohol content between 0.2-0.5 dg/L is up to five times higher than for sober drivers.

Spatial analysis is a geostatistical tool that is becoming widely used in the research to benefit the field of healthcare and several others. One of its applications comprises the identification of spatial clusters. A spatial cluster is any aggregate of events that is not merely casual, the identification of which is the subject matter of research in spatial statistics<sup>20</sup>.

This technique allows the view and description of variable distribution, aiming to identify typical and atypical patterns, enabling the development of

hypotheses. Thus, the creation of choropleth maps is a practical way to study data aggregated by areas, a form of fast translation of this information through visual perception.

A similar work has addressed hospitalization for motorcycle accidents in the region of Vale do Paraíba, in the state of São Paulo, through the geoprocessing technique, which is similar to the one used in this study<sup>21</sup>.

The objective of this study was to identify special micro-region clusters according to mortality rates resulting from traffic accidents in the state of São Paulo (SP) during the period of one year before and one year after the enactment of the Brazilian Drinking and Driving Law.

## METHODS

An ecologic and exploratory study was performed with mortality data provided by the SUS. It included the years of 2007 and 2009, chosen because they encompass a time interval of one year prior to and subsequent to the enactment of the Brazilian Drinking and Driving Law. Therefore, it was not a continuous analysis, but a comparative analysis of two periods – 2007 and 2009.

Demographic data was obtained from the Brazilian Ministry of Health. An average population for each micro-region was obtained by evaluating the estimated population in 2007 and 2009<sup>22</sup>.

Traffic accident category comprised four coded diagnoses in chapter XX of the International Classification of Diseases (ICD-10), namely: V01-V09 (pedestrian), V10-V19 (pedal cyclist), V20-V29 (motorcycle rider), V40-V49 (car occupant)<sup>23</sup>. Mortality rates per 100,000 inhabitants were divided into classes: low (up to 20 deaths), moderate (20 to 40 deaths), high (40 to 60 deaths), and very high (above 60 deaths). Geoprocessing techniques were used to georeference micro-region data according to the victim's place of residence.

Sixty-three micro-regions in the state of São Paulo were analyzed, representing a population of about 41 million inhabitants, and are presented in Figure 1.

After obtaining the mortality rate of the two years of study, new statistics were calculated by subtracting the 2007 rate from the 2009 rate. Thus, it was possible to identify the micro-regions that improved, those that worsened, and also the mortality rate. This data was categorized pursuant to the variation in the percentages of accidents: great improvement (between 10% and 20% reduction in mortality rates), slight improvement (up to 10% reduction in mortality rates), slight deterioration (up to 10% increase in rates), moderate deterioration (10% to 20% increase), and great deterioration (more than 20% increase in mortality rates).

The global Moran's index (I), first-order autocorrelation, was calculated for the study categories through

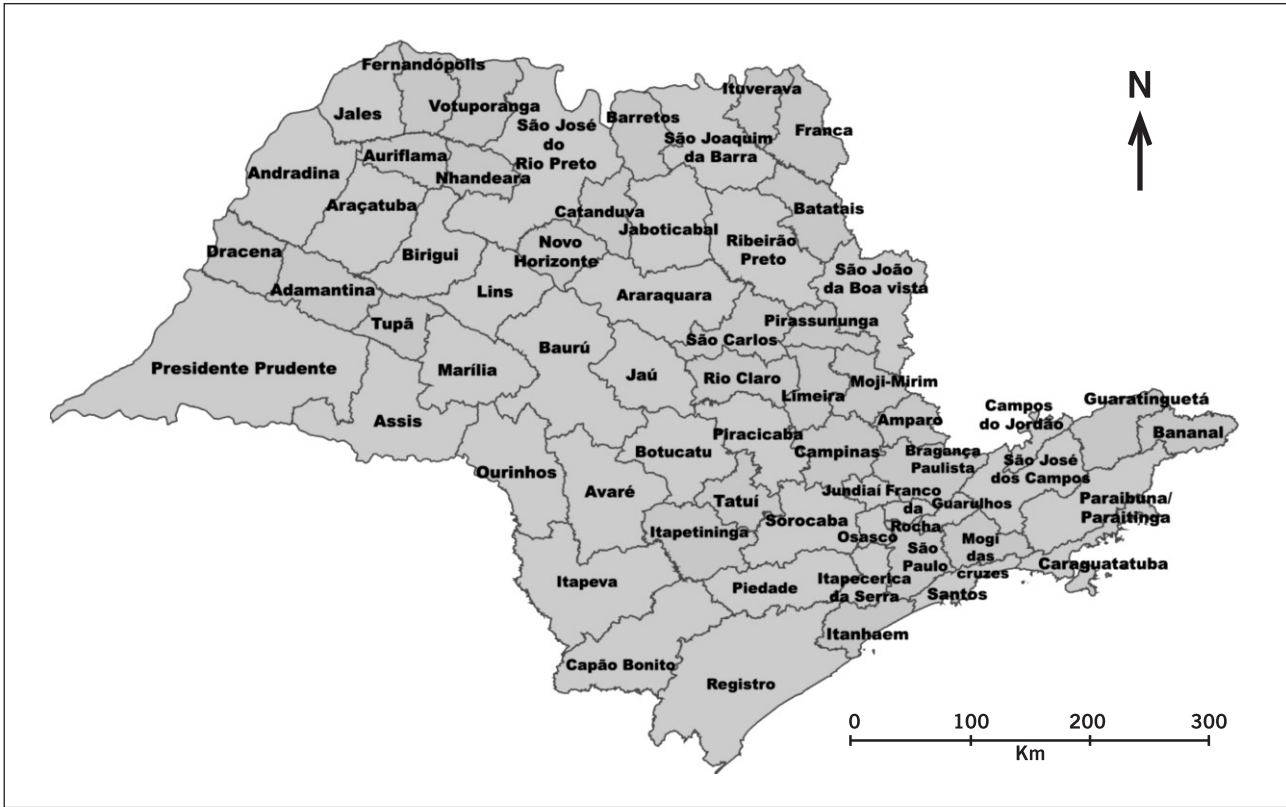


Figure 1 – Micro-regions in the State of São Paulo.

the application Terraview, which is made available by the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais -INPE). This index is expressed by:

$$I = \frac{n \sum_i \sum_j w_{(i,j)} (x_{(i)} - x)(x_{(j)} - x)}{\sum_i \sum_j w_{(i,j)} \sum_i (x_{(j)} - x)^2}$$

In this equation, “n” refers to the number of areas, “ $W_{(i,j)}$ ” is equal to the neighborhood weights, “ $X_{(i)}$ ” represents the square root of the average incidence rate for the “i” city in the study periods, and “x” refers to the average of “ $X_{(i)}$ ” for the entire study region. Moran’s index is a spatial autocorrelation that indicates the degree of spatial association in the set of information based on the product with respect to the average. Its value is contained in an interval [-1;1] and, during its calculation, it is important to establish its statistical validity by estimating the significance (p-value).

After developing the global Moran’s index, the local Moran’s index (local index of spatial autocorrelation – LISA) was analyzed through the construction of a box map, which suggests high-priority intervention micro-regions, located in quadrant 1, which are micro-regions with high rates surrounded by others that also present high values.

Choropleth maps were built for a better view of the information obtained in the study.

According to data from the National Traffic Department, in December 2007 there were 13,438,418 motorcycles and automobiles, and in December 2009, this amount reached 15,584,859, representing an increase of approximately 2,000,000 vehicles<sup>24</sup>.

## RESULTS

Deaths resulting from traffic accidents amounted to 10,269 events. In 2007, the total was 5,204 (50.68%), ranging from 1 to 1440. In 2009, a total of 5,065 accidents occurred (49.32%), ranging from 1 to 1,453. Average deaths by region were equivalent to 83 in the period of 2007, decreasing to 80 in 2009. These numbers represent a drop in the number of deaths by 1.35 percentage points, equivalent to a 2.67% decrease. It is a positive amount, but very low, as the expectation after the implementation of this law was of a massive reduction in the number of accidents.

The maximum reduction in mortality was 21.1% (micro-region of Bragança Paulista), and the maximum increase in mortality rates was 41.4% (micro-region of Presidente Prudente). Global Moran coefficients for the mortality rates of the variables studied can be found in Table 1.

**Table 1** – Distribution of the global Moran's index and its p-value assigned to the study variables on deaths in traffic accidents in 2007 and 2009

Variables	Moran's Index (I)	p-value (p)
Mortality rate in 2007	0.09	0.04
Mortality rate in 2009	0.04	0.16
Difference between the 2009 and 2007 rates	0.23	0.007

The positive spatial correlation presented in 2007 may be observed in Table 1. 2009 showed no spatial association. However, the difference between 2009 and 2007 micro-region values showed a high spatial correlation.

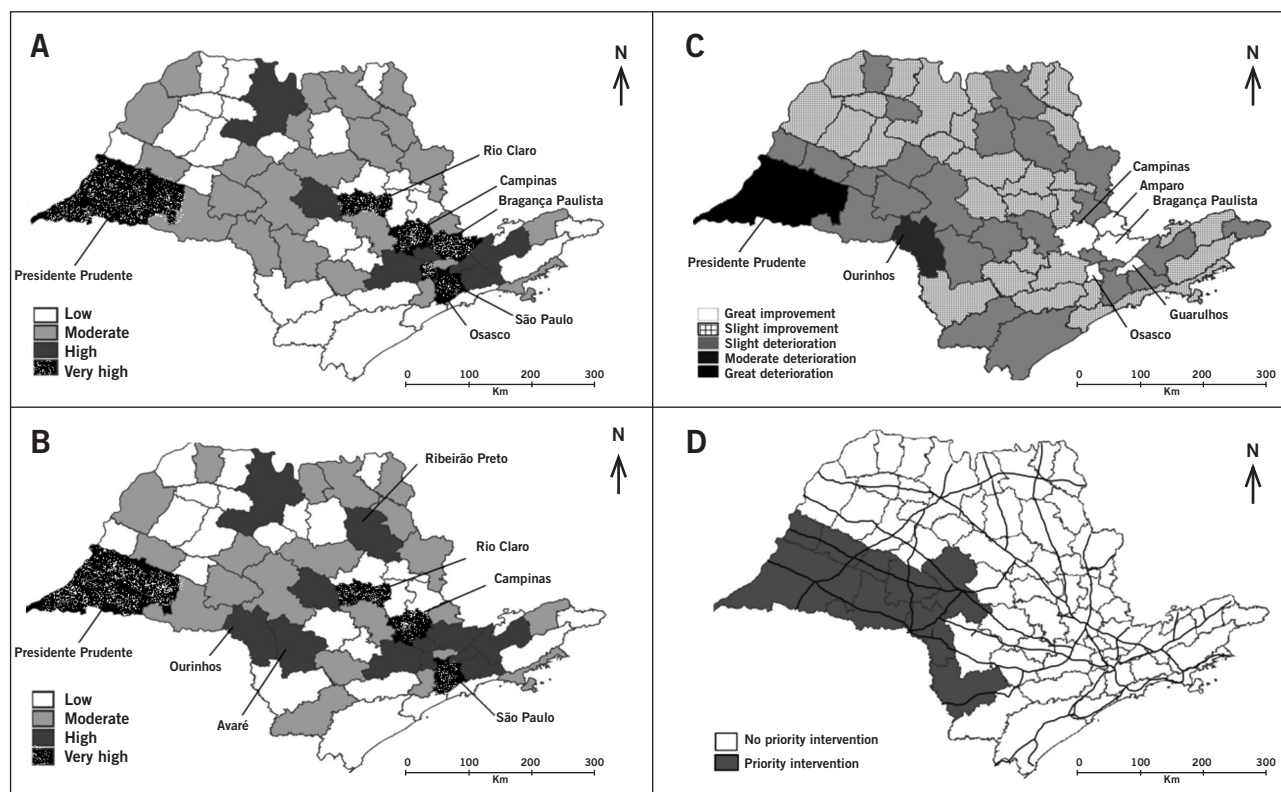
In Figure 2A it is possible to observe the spatial distribution of mortality rate in the first period. In the detail are the micro-regions that show high mortality rates, such as Presidente Prudente, Rio Claro, Campinas, Bragança Paulista, Osasco, and São Paulo.

In 2009, Figure 2B shows that the micro-regions of Presidente Prudente, Rio Claro, Campinas, and São Paulo maintained the high level of death rates, together with others that showed deterioration, such as Ribeirão Preto, Ourinhos, and Avaré.

However, when the category of differences between mortality rates in 2009 and 2007 was analyzed, it was possible to observe which were the micro-regions that showed improvement and deterioration after the implementation of the Brazilian Drinking and Driving Law.

In Figure 2C, Presidente Prudente and Ourinhos stood out with great deterioration in mortality rates. However, micro-regions such as Amparo, Bragança Paulista, and Campinas greatly improved this index one year after the Drinking and Driving Law was enacted. The great deterioration observed in both micro-regions mentioned was accompanied by a moderate deterioration in other 25 micro-regions, most in the east-west axis.

While Rio Claro is present in both periods with high mortality rates, by analyzing the difference between the rates, there was a slight improvement. Nonetheless, Campinas and Bragança Paulista, in spite of high rates in both periods, managed to achieve great improvement. This shows that, despite having delivered high values in 2009, they were lower than in 2007. Conversely, São Paulo, with high indexes, demonstrated a slight deterioration between the periods. Guarulhos and Osasco regions also improved their indexes. After presenting all this data, Figure 2D represents the box map, where micro-regions that should be given priority in actions to prevent accidents are emphasized.



**Figure 2** – Mortality Rate by traffic accidents in the State of São Paulo: (A) for 2007, (B) for 2009, (C) difference between the 2009 and 2007 mortality rate, (D) box map that identifies priority intervention micro-regions, with the region's major highways.

## DISCUSSION

This study is the first to be performed with geospatial analysis of the traffic accident mortality rate in the state of São Paulo. It may be said that more studies on the subject are extremely important to Public Health.

The Brazilian Drinking and Driving Law represents an important time milestone used in the analysis in order to verify whether its implementation would impact the number of traffic accidents.

A possible hypothesis for the high accident rates, showed in Figure 2D, is based on the presence of highways that cross these regions, such as Raposo Tavares (SP270) and Transbrasiliana (BR153). The former begins in the west region of São Paulo and ends at the border of the state with Mato Grosso do Sul, a major axis that leads to some important destinations, such as Presidente Prudente, Sorocaba, Ourinhos, and São Paulo. The latter is Brazil's fourth longest highway and the main connection from the Midwestern to the Northern regions of the country. It has heavy traffic, highly integrating the country, but its winding design and poor condition make it dangerous in some stretches. While it is important to differentiate accidents that occur in an urban area from those on highways, the data available in the DATASUS (Database of the Brazilian Unified Health System) does not make such differentiation.

The fact that most accidents occur in the east-west axis may be possibly related to the existence of roads such as SP270, which crosses part of the east-west region. On the other hand, Presidente Dutra Highway, in the stretch from São Paulo to the micro-region of São José dos Campos showed deterioration, probably due to traffic increase in these regions. On the other hand, Regis Bittencourt (BR116), which runs from SP to Rio de Janeiro and Curitiba, has a single lane stretch that is frequently the focus of accidents (Serra do Cafezal).

Although a small reduction (2.67%) in deaths caused by accidents was observed after the implementation of the Drinking and Driving Law, in Figure 2C it is notable that many regions increased mortality numbers, accounting for a total of 43% of the state of São Paulo. The small reduction in deaths may reflect occasional preventive actions, such as roadblocks. Perhaps if these actions were intensified, and their frequency increased, there would be a greater reduction in traffic accidents. It is important to note that this small reduction in deaths caused by accidents occurred in a scenario of increase in the fleet of vehicles (automobiles and motorcycles).

The World Health Organization (WHO) performed a number of studies in several countries that support the evidence that implementation and enforcement of legal measures that regulate the association of drinking and driving are effective in reducing traffic accidents<sup>25</sup>.

When the control of alcohol consumption by drivers is applied and enforced, both society and state finances benefit. For example, countries such as France, Spain, and Japan had significant success in decreasing mortality resulting from accidents with the control of alcohol consumption.

It is worth mentioning that the use of alcohol is one of the main causes of traffic accidents, greatly impacting on violence rates. However, other factors, such as improper maintenance of vehicles, poor signalization, legal or illegal drug abuse, and improper road maintenance may cause and/or increase the damage caused by accidents.

The expected impact of alcohol policies is the global reduction in accidents. A study conducted in Brazil in 2008 has showed a positive result when comparing the number of hospitalizations and expenditures in the six-month periods before and after the Law<sup>8</sup>. In the second semester, there was a drop of 28.3% in hospitalizations and of 35.5% in governmental spending.

However, in 2009, Moura et al. demonstrated an initial drop in the association of drinking and driving soon after the Drinking and Driving Law came into effect; later, there was an increase in the months of September and October, reaching amounts higher than the previous semester in December, 2008<sup>26</sup>.

A study in Diadema concluded that almost 20% of the researched drivers were driving with alcohol levels greater or equal to that permitted by law, according to breathalyzer<sup>4</sup>.

A limitation of this study is based on the lack of integration between the Brazilian Healthcare System and the Transportation System, making it difficult to perform studies by accident location.

The need to develop social projects relating to education and awareness, together with effective surveillance policies aiming at restricting alcohol consumption by drivers, control of alcohol advertisements, as well as enforcement of the prohibition of alcohol sale to minors and along the roads is essential to the country.

A consideration should be made regarding this study, as it has not used the fleet of vehicles as an accident-influencing factor. This data was not used because, even with the increase of 2,000,000 vehicles, there was no increase in accidents, but rather a small reduction, as mentioned above.

## CONCLUSION

Finally, it was possible to identify spatial patterns of mortality in the state of São Paulo. It was observed in this study that, despite the restrictive law on alcohol being in force, many micro-regions presented deterioration of their rates, indicating locations where surveillance actions should be reviewed in order to become more effective for the prevention of traffic accidents and for road safety.

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