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GIS SPATIAL TOOLS FOR TRAFFIC ACCIDENTS: ANALYSIS WITH HEAVY VEHICLES ON HIGHWAYS IN RIO DE JANEIRO

Samir Bressane[1*], Rafael Nunes[2] and Nélio Pizzolato[3]

[1]*Research Scholar. Department of Civil and Environmental Engineering. Pontifícia Universidade Católica do Rio de Janeiro, R. Marquês de São Vicente, 225 - Rio de Janeiro, 22541-041, Brazil. e-mail: samir_borges@hotmail.com*

[2]*Professor of Cartography and Geoprocessing. Department of Geography. Pontifícia Universidade Católica do Rio de Janeiro, R. Marquês de São Vicente, 225 - Rio de Janeiro, 22541-041, Brazil. e-mail: rsngeo@gmail.com*

[3]*Professor of Engineering Emeritus. Department of Industrial Engineering. Pontifícia Universidade Católica do Rio de Janeiro, R. Marquês de São Vicente, 225 - Rio de Janeiro, 22541-041, Brazil. e-mail: ndp@puc-rio.com.br*

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Abstract: Allied to the incorporation of vehicles in the daily life of society, a relevant social problem emerges: traffic accidents. The impact of these events is such that they cost most countries around 3% of their Gross Domestic Product (GDP). In Brazil, a mostly road country, this network concentrates about 60% of the volume of cargo and 90% of the total passengers transported. When it comes to heavy vehicles, the situation is even worse, exposed to exhausting working hours, truck drivers work in an environment where risk, lack of security, road infrastructure and isolation can lead to greater accidents. In Rio de Janeiro, the vehicle fleet is growing and needs ways to control the risks of accidents. With the evolution of geotechnologies, georeferenced studies, Geographic Information System (GIS) have allowed the use of spatial statistical techniques and optimization for decision making. This work aimed to study GIS tools in the analysis of traffic accidents involving heavy vehicles on federal highways in the State of Rio de Janeiro. Maps with the regions with greater incidence and severity of accidents are highlighted. The work demonstrated the capabilities of GIS, in the light of current literature and methodologies, in the identification of critical points and, by using a database, the methodologies can be replicated, improved, or expanded in other regions.

Keywords: Traffic accident; geographic information system; federal highway; heavy vehicle

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* Correspondence to: Samir B. Bressane, Tel.: +55 21 971191533.

INTRODUCTION

Allied to the incorporation of the vehicle in the daily life of society, a relevant social problem emerges, traffic accidents. While in developed countries great effort is done to control them, in developing countries, with an unstable growth, they appear as an expanding problem (Marin & Queiroz, 2000). The impact of these events is such that these accidents cost most countries around 3% of their Gross Domestic Product (GDP) (Goniewicz *et al.*, 2015; WHO, 2018). Traffic injury is now the leading cause of death for children and young adults aged 5 to 29 years. And it presents itself as the eighth leading cause of death in all age groups, more than AIDS, tuberculosis, and diarrhea (ITF, 2017; WHO, 2018).

In Brazil, roads concentrate about 60% of the cargo transported (and 90% of the total passengers). Reports, referring to 2016 data, show that Brazil appears in third place among the record-breaking countries in traffic deaths, behind only India and China (WHO, 2018). When it comes to heavy vehicles, the situation is even worse. According to a report by the Ministry of Transport, Ports and Aviation, trucks represent about 6% of the vehicle fleet in Brazil, however they are involved in 16.7% of all accidents, and with greater severity, in federal roads (Brasil, 2017). Exposed to working hours, often exhausting, truck drivers work in risky situations, in which the lack of security and time away from their family members are some of the main negative points of the profession (CNT, 2019).

Rio de Janeiro State has a rising fleet, estimated at about 6,725,822 vehicles (IBGE, 2020). Information from the Transit Dossier, a survey carried out by the Public Security Institute and DETRAN-RJ, shows that in 2018, 1,957 people died and 27,520 were injured in traffic accidents in Rio de Janeiro State, an average of six fatal victims every day (Boechat, 2019). Traffic accident locations are crucially important information for understanding the causes and implementing traffic safety measures. With the evolution of geotechnologies, georeferenced road studies have been using statistical techniques, for analysis and optimization in decision-making, through Geographic Information Systems (GIS) (Hashimoto, 2016; Silva *et al.*, 2009).

This work aims to study GIS tools in the analysis of traffic accidents, using data of heavy vehicles on federal roads of Rio de Janeiro State. The methodology adopted for the elaboration of this research was exploratory research, with a review of critical accident spots studies as well as the existing GIS methodologies in the literature. With a subsequent case study application and methods comparison.

Studies and Methods of Traffic accident analysis

According to NBR 10697 (ABNT, 1989), a traffic accident is any non-premeditated event that results in damage to the vehicle or its load and/or injuries to people and/or animals, in which at least one of the parties is moving on land roads or areas open to the public. Identifying the causes can assist in creating adequate accident prevention policies that make roads safer. The identification of places with a higher incidence of accidents is a way of improving the safety levels of the road network, establishing priorities (CNT, 2019).

The methodologies for identifying critical traffic accident locations are of fundamental importance, together with the choice of the most appropriate methods for the studies' effectiveness (Gold, 1998; Brasil, 2002; DNIT, 2009). The most widespread methods found in the literature are, in general, classified into: Numerical, Statistical, Traffic Conflicts, and Road Safety Auditing (Brasil, 2002; Martinez & Lopes, 2010).

From the available methods, the Numerical can be considered the simplest to calculate. Critical locations are determined by calculating the number of accidents and accident rates. Numerical methods are subdivided into Absolute and Relative.

a) Absolute: The <u>Number of Accidents Technique</u> considers as critical locations those with more accidents than the arithmetic average of accidents recorded in the respective segments (Brandão, 2007). And the <u>Accident Severity Technique</u> considers the frequency and severity of accidents (they use the concept of Standard Severity Unit - UPS) (DENATRAN, 1987; Brasil, 2002);

b) Relative: The <u>Accident Rate Technique</u>, the number of traffic accidents is related to the traffic volume of the respective location (DNER, 1986; Pline, 1992). And the <u>Severity Rate Technique</u> is the severity of accidents, expressed in UPS, and related to the volume of traffic on the site (Brasil, 2002).

Statistical Methods involve the use of probabilistic, spatial mathematical models, spatial techniques, and tests of statistical significance to determine places of increased risk of accidents

(Khorashadi *et al*., 2005). The Traffic Conflicts method can be defined as an event involving two or more road users, in which the action of one of them causes the other to make an evasive maneuver to avoid a collision (identifying the factors that lead to risky behavior) (Parker *et al*., 1989). The Safety Audit can be defined as a formal process of systematic safety checks on road sections. It is based on the preventive action of checking risk factors on existing roads, recently opened or even in the design phase (Kanellaidis & Vardaki, 2011).

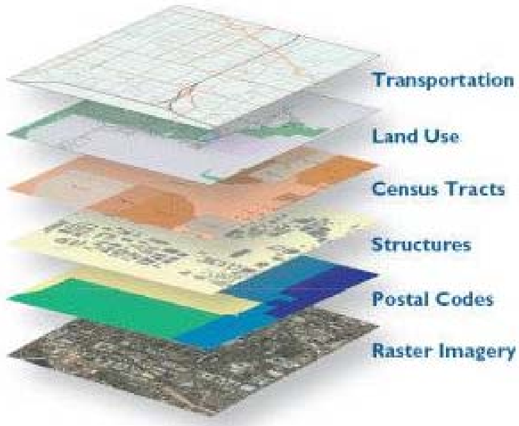


Fig. 1 Integration of data and layers. Source: ESRI, 2004.

GIS and Spatial Analysis

GIS are designed to aggregate spatial data from different sources into a database, usually using digital data structures and representing spatially variable phenomena as a series of data layers. The computational treatment of geographic data and the respective georeferenced attributes are located on the Earth's surface represented in a cartographic projection. Layers allow dealing with information plans from the most diverse sources, allowing the user to carry out analysis, create and edit maps (**Fig. 1**) (Câmara *et al*., 2004a).

Studies and analysis, with the spatial bias, have become more and more common, due to the availability of low-cost and friendly interfaces GISs. Many available data, such as census, have a spatial reference that can be analyzed statistically. However, a fundamental characteristic of spatial analysis is the use of geographic coordinates in the process of collecting, processing, analyzing, and describing data (Câmara *et al*., 2004b).

It recognizes that all sites have an intrinsic degree of uniqueness due to their position in relation to the rest of the space system. In line with this statement, there is the widespread Tobler's Law (1970), also known as the first law of geography: "I invoke the first law of geography: everything is related to everything else, but near things are more related than distant things." (Miller, 2004, p. 284).

Spatial analysis tools can be divided into Selection, Manipulation, Exploratory Analysis and Confirmatory Analysis. Selection is the choice and sampling of observational database units, with sampling results and procedures. Data Manipulation covers the disposition, aggregation, overlap and interpolation procedures necessary to create spatial data. Exploratory Analysis seeks to describe global and local spatial distributions, discover patterns of spatial association (clusters), suggest spatial instabilities, and identify atypical situations (outliers). Confirmatory Analysis has as a starting point a theoretical model, such as hypothesis testing, modeling, self-regression, validation, necessary to implement multivariate analysis with spatial components (Anselin, 1992; 1996).

Spatial analysis is used to specify geographically the places where phenomena of interest occurred and to evaluate specific distribution patterns through the visualization of maps. The most used spatial analysis techniques in GIS, in the literature, for analyzing traffic accidents are (Satria & Castro, 2016):

- KDE (Kernel Density Estimation) produces a scan as a way of analyzing geographically the density of accidents;
- Global Moran's I is a statistical tool that measures the spatial autocorrelation of accident sites (Moran, 1948);
- Local Moran's I characterize each location with an index value that denotes the individual contribution to the global autocorrelation measure. It is considered a Local Indicator of Spatial Association (LISA) (Moons *et al*., 2009);
- Getis-Ord Gi* is also one of the LISA indexes that looks for specific areas in an image that have similar or different groupings of values (Getis & Ord, 1992).

Traffic accident studies with GIS and Spatial Analysis

Although GIS has been used for more than thirty years, it has recently been even more used in the field of road accidents. In addition to promoting the connection between various types of data and maps, a GIS can manipulate and visually display various types of traffic data to facilitate understanding (Jayan & Ganeshkumar, 2010).

Ahmadi *et al.* (2017) developed a study to specify the capabilities and resources of a GIS in managing traffic accident information. The authors highlighted: Resources to save and recover data; Resources and tools for analyzing accidents and hotspots; Ability to use multiple databases; Features of system design, user interface and graphical interface design; Resources for output and report generation; Resources to support the decision to locate emergency centers, police stations and hospitals.

The use of GIS in promoting road safety is seen in the study by Soleimani & Jahani (2009), in which GIS tools were identified as the best solution for collecting, saving, and presenting geographical information related to traffic accidents. The research of Badin *et al*. (2002) developed a GIS prototype for planning and managing road signs, to update and implement all vertical traffic signs, and to create a georeferenced database associated with each existing sign.

Meinberg (2003) presents a methodology for modeling and developing a georeferencing project for traffic accidents. Through routines for creating thematic maps and developed interfaces, the program, called "Geotrans" made it possible to analyze the type of accident, the severity, the period, and the location. Schmitz (2011) used GIS software to spatially analyze critical segments in highways. Through the GIS, several alphanumeric data analysis and visualization interfaces were created. The overlapping satellite images, the road network, the segments, and points of traffic accidents allowed a better perception of the problems and made it possible to intervene with an extended diagnosis.

When it comes to the use of spatial analysis in GIS for traffic accidents in Rio de Janeiro, the literature is still scarce, especially for heavy vehicles.

DATA AND ANALYSIS METHODS

Case Study: Heavy vehicles accidents in Rio de Janeiro

The study area is geographically limited by Rio de Janeiro State. The state is in the southeastern region of Brazil and, according to the IBGE (2020), has an area of about 43,696.054 km^2. Rio de Janeiro is divided into 92 cities and 8 Government Regions. The Regions are: Metropolitana, Noroeste Fluminense, Norte Fluminense, Baixada Litorânea, Serrana, Centro-Sul Fluminense, Médio-Paraíba and Costa Verde. The road system data studied concerns only the federal roads under the supervision of the PRF (Federal Roads Police). The federal roads that cross the state (DNIT, 2020) and were the object of this study are: BR-040, BR-101, BR-116, BR-354, BR-356, BR-393, BR-465, BR-485, BR-493 e BR-495 (**Fig. 2**).

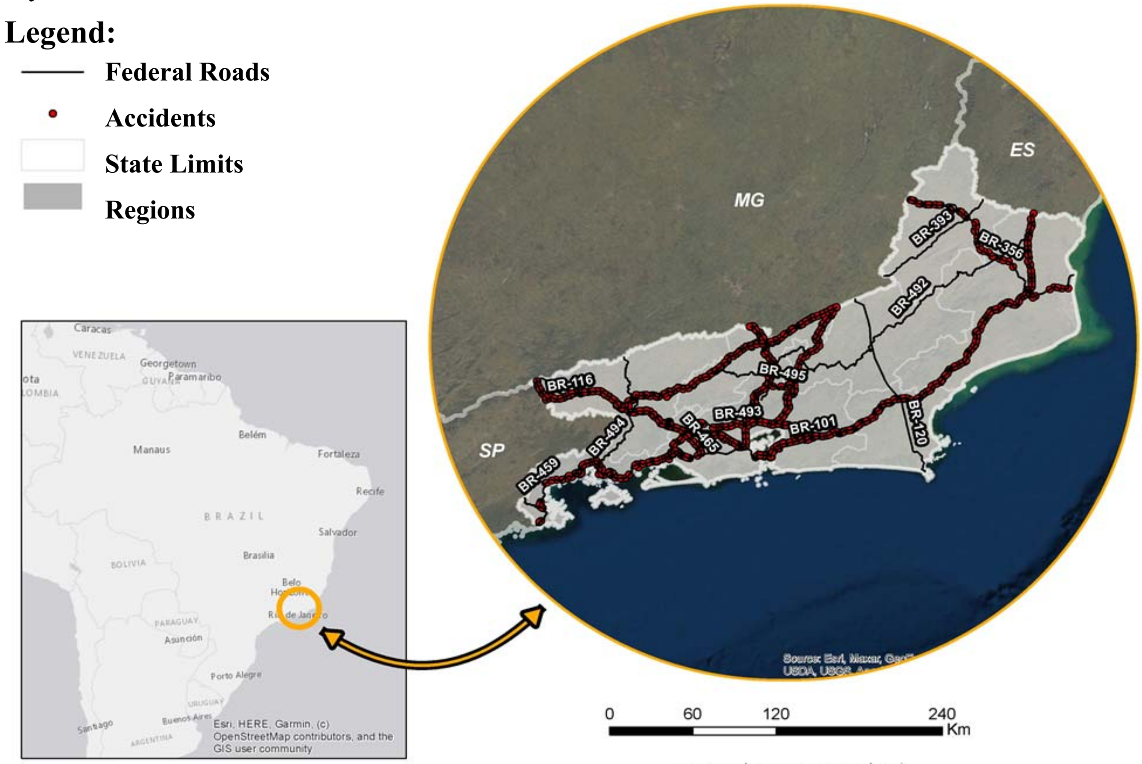


Fig. 2 Rio de Janeiro State with heavy vehicle accidents (2017-2019) on federal roads. Source: Prepared by the authors.

Table 1. Heavy vehicle accidents severity per year on federal roads in Rio de Janeiro. Source: Brasil, 2019.

Year	Total accidents	No Victims	Light Injuries	Serious Injuries	Fatal
2017	1603	714	619	152	118
2018	1251	385	598	175	93
2019	1122	300	531	174	117

The traffic accident data and information for the research were collected through electronic spreadsheets obtained in the traffic accident reports of the Federal Roads Police Department (DPRF) (Brasil, 2019). The use of data from three years (2017, 2018 and 2019), follows the literature for a significant analysis (Isen *et al*., 2013; Al-Omari *et al*., 2019). Traffic flow, volume data and maps of the road network (National Road System - SNV 2020) were obtained from the National Department of Transport Infrastructure (DNIT, 2020). **Table 1** shows the general distribution of data that was used in the analysis, addressing the severity of the accident and the year of occurrence.

Software and Data Processing

The software chosen was ArcGIS 10.7.1, which is an integrated set of GIS software and tools, produced by ESRI. The UTM (Universal Transverse Mercator) projection of the Geocentric Reference System for the Americas (SIRGAS 2000), the official geodetic system of reference in Brazil, was maintained as standard. The PRF data includes vital accident data, such as the date and time, types of accidents, vehicles involved and severity of accidents. Spiderplots, also known as radar charts, were made for understanding the distribution of temporal data. This method highlights the chronological nature of the data and helps visualize the variation of accidents over time.

Kernel Density Estimation

KDE is an interpolation technique, which is a method for generalizing points of interest in a defined area. One of the advantages of this representation, particularly for road accidents, is that it can provide a more realistic view of a continuous model of critical point patterns (Anderson, 2007). **Eq. (1)** uses a quartic kernel developed by Silverman (1986) and is calculated for each location where it is desired to estimate density of events. As a scan is created, calculations are applied to the center of each cell (pixel) in the output (ESRI, 2019).

$$\hat{\lambda} = \sum_{i=1}^{n} \frac{3}{\pi\tau^2}\left(1 - \frac{h_i^2}{\tau^2}\right)^2 \tag{1}$$

where:
$\hat{\lambda}$ → density in local s
τ → Bandwidth
h → the distance between point i and the (x,y) location

Yearly maps were created using the KDE to create a surface (Raster) of the accident density. For the kernel maps, the bandwidth of 2000 meters, and the cell size of 200 meters were chosen. These parameters defined the region (neighborhood) in which KDE was calculated.

Spatial Statistics

The spatial statistical analysis was separated in two moments, initially made using the Incidence of points as the main attribute, and then using the Severity. For Incidence, a GIS tool was used, that identifies points at a certain distance from others, using a 200 m radius for assuming the same coordinate for them. It then combines coincident points and creates a new attribute called *ICount* to store the union of all incidents at each location (Prasannakumar *et al*., 2011).

This research created a weight for Severity, which was used as the main attribute for spatial statistical analysis. Based on values used in the literature, the weights 1, 3, 7 and 13 were chosen, for accidents without victims, accidents with light injuries, serious injuries, and fatal accidents, respectively (DNER, 1986; DENATRAN, 1987; Brasil, 2002; Aghajani *et al*., 2017).

To perform the spatial statistics in GIS, like other authors (Moons *et al*., 2009; Agyakwah, 2018), the Global and Local Moran's I index were chosen. The weight for Incidence was the *ICount* attribute and for Severity it was the *WeightSeverity* attribute (1, 3, 7 or 13). The Global Moran's I index assesses its significance through three result variables: Moran's index, Z-score and P-value. If the values in the data set tend to cluster spatially, the Moran's Index will be positive. This index usually varies between -1.0 and + 1.0 (ESRI, 2019). A high Z-score and a small P-value indicate a significant hotspot. A low negative Z-score and a small P-value indicate a significant coldspot. P-values have ranges of levels of statistical significance of 0.10, 0.05 and 0.01, respectively, confidence level of 90%, 95% and 99% (Getis & Ord, 1992).

The **Eq. (2)** represents the calculation for Global Moran's I index:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=0}^{n} z_i^2} \quad (2)$$

where n → number of points, Z_i → the deviation of an attribute for feature i from its mean (Xi - $\overline{X}$), $w_{i,j}$ → the spatial weight between feature i and j, and S_0 → the aggregate of all the Spatial weights.

The verification of hotspots locally, statistically significant, with the Local Moran's I index, can be given by the expression described in **Eq. (3)**, created by Anselin (1995), applying the concept of LISA.

$$I_i = \frac{n}{(n-1)s^2} (x_i - \bar{x}) \sum_j wij(x_j - \bar{x}) \quad (3)$$

where n → the total number of points, x_i → represents the attribute in the local of accident I, $\bar{x}$ → the average value of the accidents attribute in all study area, wij → represents the proximity of point i's and point j's locations, and S^2 → variance of observed values.

The Local Moran's I gives as an output a layer with five categories of hotspots: Non-significant, High-High Cluster, High-Low Outlier, Low-High Outlier and Low-Low Cluster. Only locations with statistical significance (P-value <0.01) and High-High clusters (High incidence of high values) were selected as hotspots for this research.

Numeric-Relative Method (DENATRAN, 1987)

This methodology was created by the National Traffic Department (DENATRAN) and the Federal University of Rio de Janeiro - COPPE / UFRJ. A Standard Severity Unit (UPS) is calculated for each segment (1 km) of the highway, which can be expressed by **Eq. (4)**.

$$UPS = A.S.V. + A.C.V. \times 5 + A.C.F. \times 13 \quad (4)$$

where A.S.V → the number of accidents with no victims, A.C.V. → the number of accidents with victims, and A.C.F. → the number of accidents with fatalities

This methodology can assess the risk level of highway segments considering the influence of traffic volume relative to accidents (Paro, 2009; Schmitz, 2011; Massaro, 2018). The Severity Rate can be expressed by the **Eq. (5)**.

$$T.S. = \frac{UPS \times 10^6}{P \times VMD \times E} \quad (5)$$

where T.S → Severity Rate in UPS by million vehicles, UPS → Standard Unit of Severity, P → Period of study in days, VMD → Average Daily Traffic Volume, and E → Extent of the segment (in km).

The same methodology was used again, however, to obtain the Accident Rate (T.A.), as Incidence of accidents. For this purpose, the value of UPS is replaced in **Eq. (5)** by the total number of accidents in the respective sections.

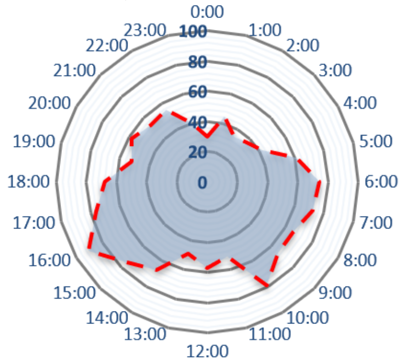
RESULTS AND DISCUSSIONS

Temporal Distribution

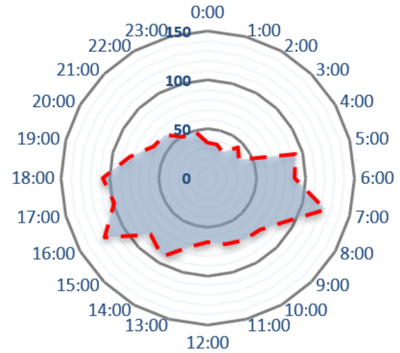
The number of accidents was higher during the summer period (higher rainfall), between December and March. Accidents were concentrated on weekdays (most professional drivers' workdays), with highest peaks on Fridays. **Fig. 3a** shows the general trend of accidents with no victims, with peaks around 7:00 and 16:00. For those with light injuries (**Fig. 3b**), the spiderplot begins to change shape and widen to the sides, but still maintaining throughout rush hours. In **Fig. 3c**, addressing accidents with serious injuries, the general propensity changes and the graph is scattered. Peaks in the nighttime at 21:00 appear and this trend is confirmed in **Fig. 3d**, with fatal accidents. **Fig. 3d** shows highest number of fatal accidents occurring between 23:00 and 00:00, as well as a distribution at 4:00 and 6:00 in the morning. Accidents in these periods tend to be more severe, drivers are more tired, less attentive, with less visibility and speeding (Le *et al.*, 2019; Dabalo, 2020).

In **Fig. 4** the highest volume of accidents is concentrated in Metropolitana region, in the cities of Rio de Janeiro, São João de Meriti, Duque de Caxias, Nova Iguaçu, Itaboraí and Niterói. Another prominent region is Médio-Paraíba, which, after Metropolitana, is the most industrialized in Rio de Janeiro State. This region has accidents concentrated in the cities Piraí, Barra Mansa and

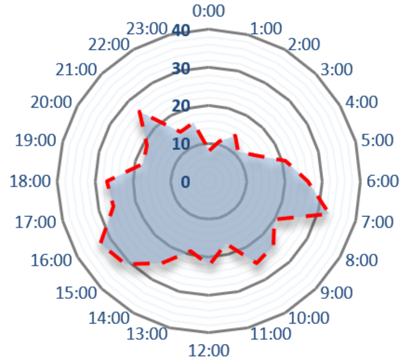
a) No Victims



b) Light Injuries



c) Serious Injuries



d) Fatal

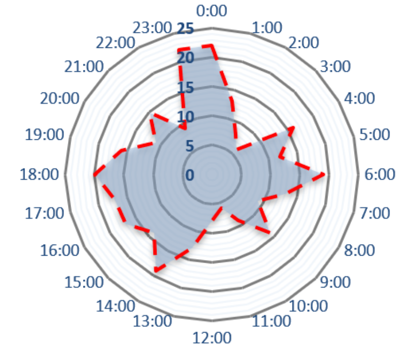


Fig. 3 Severity of accidents by hour. Prepared by the author (2020).

Kernel Density Estimation

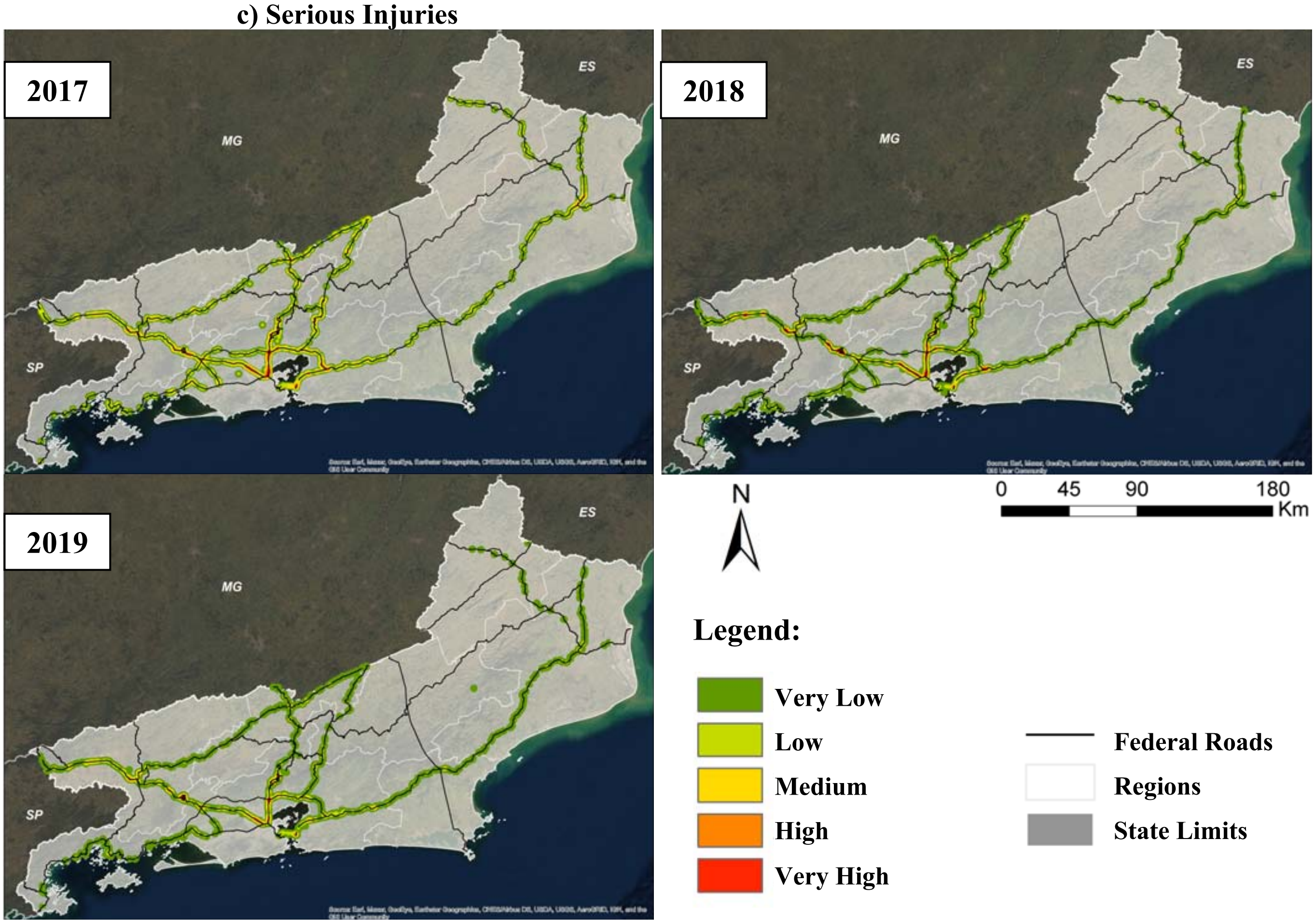


Fig. 4 Kernel Density Estimation by year, 2017, 2018 and 2019. Source: Prepared by the authors (2020).

Resende. The method of grouping natural breaks (jenks) was used, separating the categories of values to maximize the differentiation between classes (Plug *et al*., 2011; Choudhary *et al*., 2015). KDE has been widely used for road accidents due to its simplicity and ease of understanding (Xie & Yan, 2008; Jayan & Ganeshkumar, 2010, Prasannakumar *et al*., 2011; Choudhary *et al*., 2015, Shafabakhsh *et al*., 2017; Le *et al*., 2019).

Spatial Statistics

Incidence of accidents

Using the Global Moran's I index, the spatial autocorrelation of events, for the entire area, was obtained with a Clustered outcome. The Z-score and the Moran Index found were approximately 17.14 and 0.38, respectively, which represents that the events have a strong spatial autocorrelation. The P-score <0.01 demonstrates a statistical significance greater than 99%.

The Local Moran's I index resulted in the map in **Fig. 5**. It is noteworthy that, for this research, only the "High-High" clusters (P-score <0.01 and Z-score > 2.58) were adopted, that is, the high concentrations of high numbers of accidents. 66 hotspots were found that met these requirements. The critical points of incidence of accidents are in similar areas to the ones of high density in KDE. The difference is that, after Moran (I) Local, there is a greater accuracy and statistical significance of the hotspots presented.

Severity of accidents

The result for the Global Moran's I index for Severity had a Z-score and a Moran index of 3.05 and 0.04, respectively. Demonstrating that the events have also spatial autocorrelation (less intense than the Incidence of accidents). The P-score <0.01 represents a statistical significance greater than 99%. 97 "High-High" critical points were found

Here, it can be seen, from the values found, that the severity of accidents is less concentrated (clustered) and more dispersed for heavy vehicles in Rio de Janeiro State. With a certain accumulation in the mountainous region of the state. Previous conclusions from the Global Moran's I values were confirmed with the analysis of the Local Moran's I indexes. The hotspots identified for Severity were more dispersed across the map and demonstrated that Severity and Incidence are distinctively distributed. Different regions demand different approaches, regarding to the quantity and how severe are these accidents (**Fig. 6**).

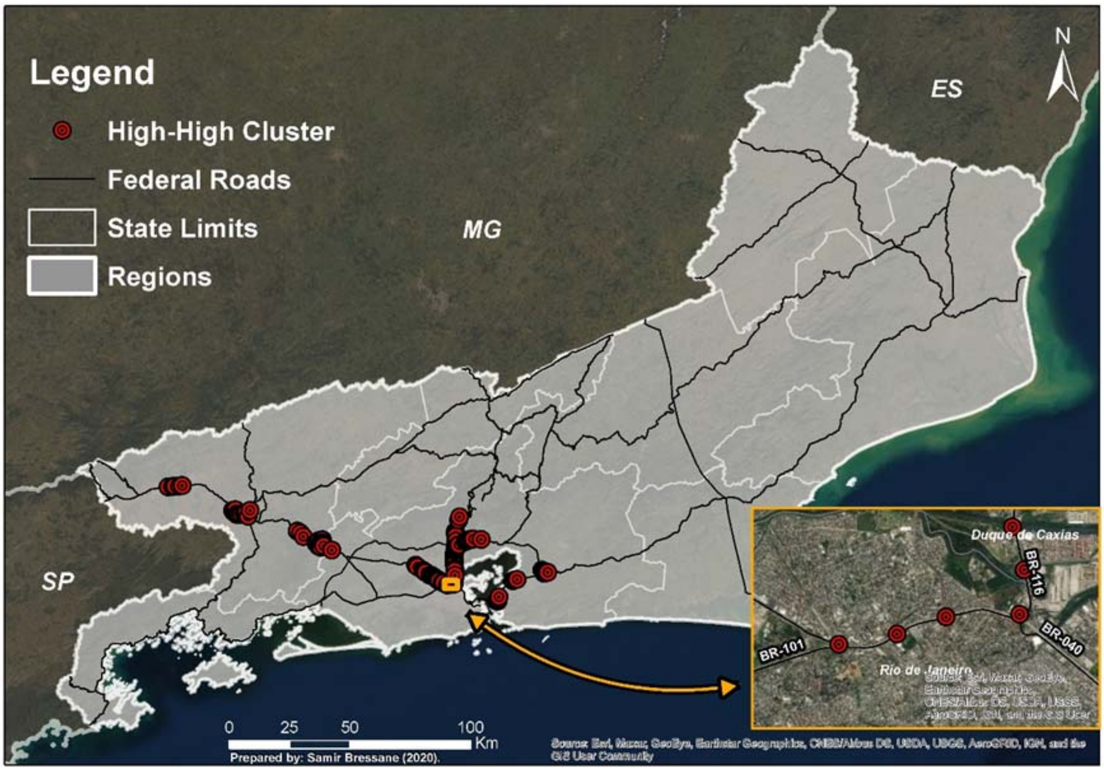


Fig. 5 Hotspots High-High from Local Moran's I for accident Incidence. Prepared by the authors (2020).

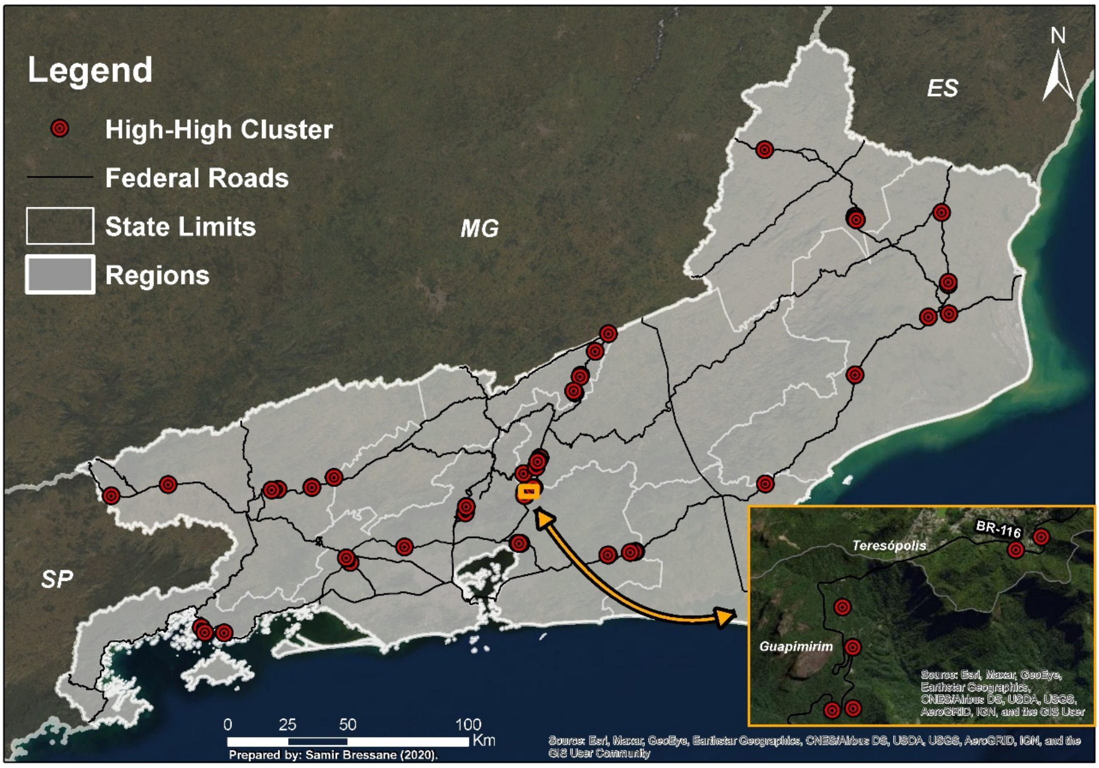


Fig. 6 Hotspots “High-High” from Local Moran’s I for accident Severity. Prepared by the authors (2020).

DENATRAN (1987) Method

Accident Rate

After organizing the accidents and calculating the rates in the DENATRAN (1987) method, the results were obtained for all sections of 1km of the highways. The Accident Rates found for the twenty most critical segments ranged between 2.88 and 7.89. The three sections with the highest Accident Rates are at the beginning of BR-493, in the municipality of Itaboraí, close to the intersection with BR-101 (**Fig. 7**).

Severity Rate

The Severity Rates found for the twenty most critical segments ranged between 14.67 and 35.94. Many segments of BR-493 were also listed, with the addition of some segments more in the North and Northwest Fluminense regions on BR-101 and BR-356, respectively **(Fig.8)**.

Comparison between methodologies

The KDE in this research proved to be a very good tool for visualization and direct representation of accident densities. However, it lacks more information and attributes, but it remains as a good tool to complement others. To facilitate the understanding of the results and better compare the other methodologies, the twenty segments identified as most critical, in the methodology of DENATRAN (1987), were mapped and plotted within the GIS software. Then, the results of the twenty hotspots, found through spatial statistical analysis, with the highest Z-scores (responsible for the degree of data clustering), were added to this map (**Figs. 7** and **8**).

An advantage of the DENATRAN (1987) method is considering and balancing the results with the Traffic Volume, but it can also be limiting factor. The volume seems to be very significant for the result of the methodology. Roads with lower average volumes obtained the highest rates, both for Accident Rate and Severity Rate. On the other hand, DENATRAN (1987) manages to obtain a numerical result (score) for each segment of the road, obtaining a complete ranking of all sections of all highways. The GIS spatial analysis methodology has in favor statistically significant results and better precision with coordinates and including areas outside of formal highways. Local Moran’s I Index also gives coldspots and outliers, even though they were not objects of study in this work, they can provide relevant information about the distribution or clustering of the incidence and/or severity of accidents.

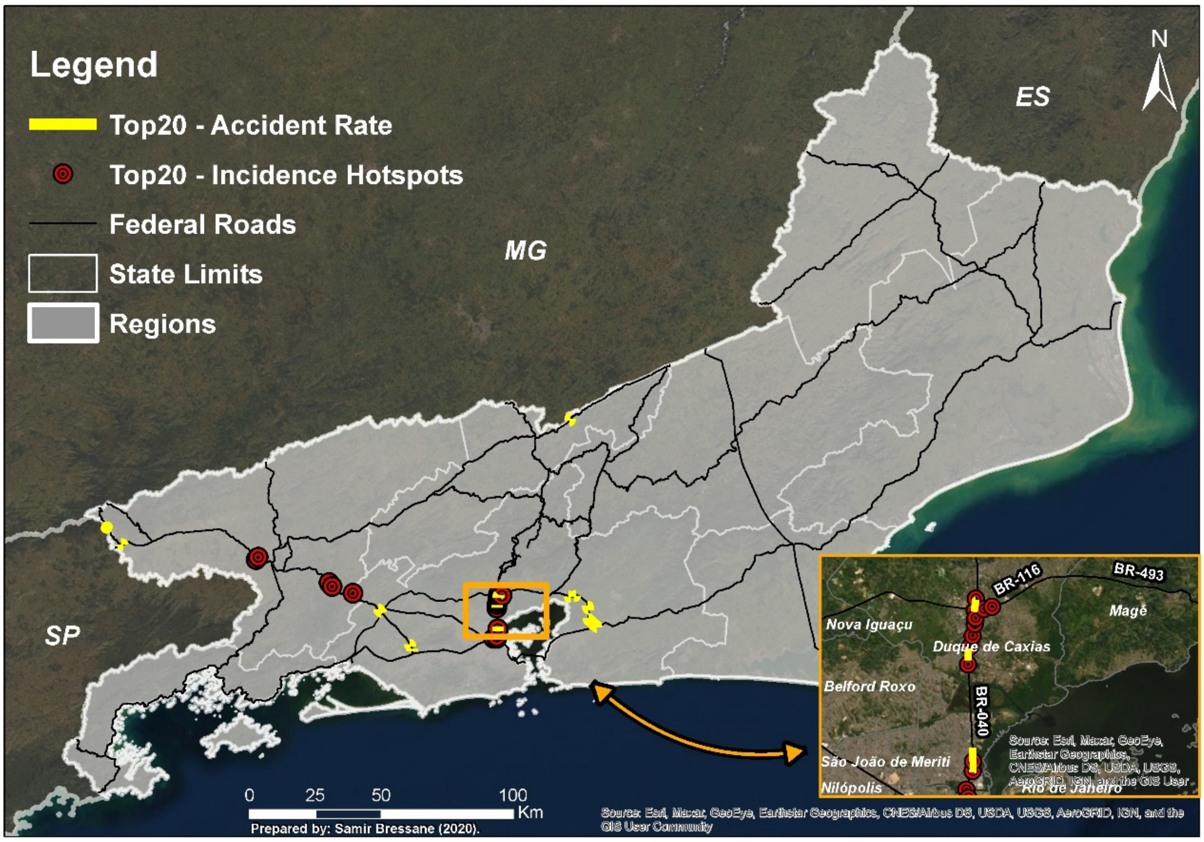


Fig.7 Comparison in GIS between DENATRAN method and Hotspots for accident Incidence. Source: Prepared by the authors (2020).

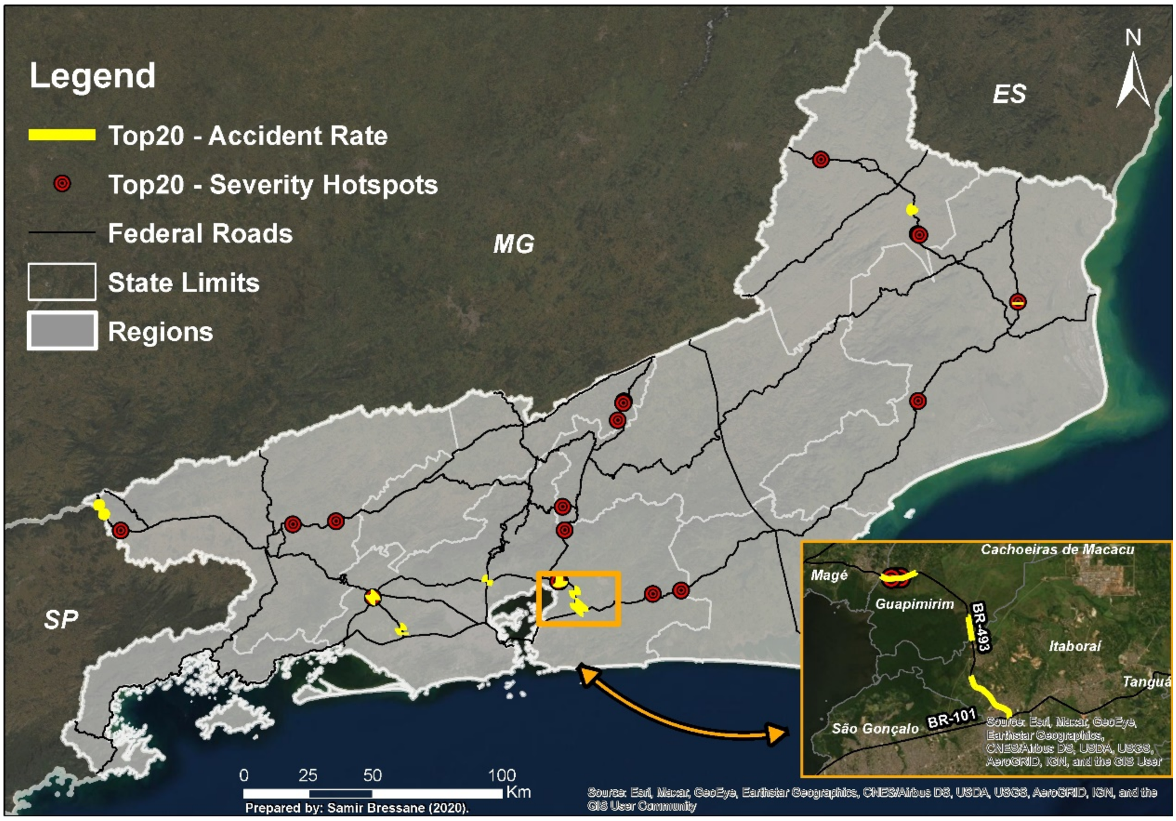


Fig. 8 Comparison in GIS between DENATRAN method and Hotspots for accident Severity. Source: prepared by the authors (2020).

Other possible features in GIS for traffic accidents

The tools in GIS in this research represent a small part of the possibilities for traffic accidents. The information in these databases goes beyond just geographical coordinates. In the work of Wolff & Asche (2016), GIS was used, together with a three-dimensional geovirtual environment, to identify hotspots of crimes. The work of Ye *et al.* (2014) evaluated an approach with GIS in the production of hotspots for ADAS (Advanced Driver Assistance Systems). The prospects for possible applications on mobile platforms, smartphones and vehicle telematics systems are highlighted. Real-time data can be analyzed to develop new ways of understanding traffic.

CONCLUSIONS

From this research, the following statements can be made. The heavy vehicle accidents in Rio de Janeiro State were accumulated during rush hours. Even with the lack of statistical significance, KDE was found as an effective way of representing traffic accident data. Spatial analysis in GIS have shown great capabilities for traffic accidents. The use of the Global Moran's I index, for Incidence of accidents, demonstrated strong spatial autocorrelation and the presence of significant clusters, and the Local analysis found hotspots in places similar to KDE. The use of the Global Moran's I index for Severity showed significant spatial autocorrelation (less than the Incidence) and the presence of clusters, and the Local Moran's I index found hotspots more dispersed throughout the state, especially in the mountainous area. Using DENATRAN's (1987) method, the Accident and Severity Rates were found for the twenty most critical segments, having a significant influence of the traffic volume.

This research demonstrated the capabilities of the GIS in the identification and representation of critical accident points in Rio de Janeiro State for heavy vehicles, which can be replicated, improved, or expanded in specific cities, highways, or segments. The techniques for statistical approaches, together with the perception and storage of database in GIS, are little explored by the traffic management agencies and institutions in Brazil. With the advancement of technologies, databases are becoming increasingly relevant. Critical points analysis can be done on-line and fed back instantly by records of police reports. This information is very valuable and can even be used by routing applications and auxiliary systems to drivers and companies.

As recommendations for traffic authorities, this research mentions: a) Increase the points and frequency of vehicle counting. b) Maintain a national standard in computerized systems for the collection, processing and storage of traffic accident data and the road system. c) Improve, standardize, and continuously train the workforce in data recording and geographic coordinate accuracy.

For future studies, this research suggests testing methodologies with different variables in spatial analysis through GIS. Also, the replication of GIS methodologies in smaller areas, thus being able to visit the most critical places, register the geometry, drainage, signaling and other environmental conditions to propose more specific corrective measures.

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