GEOGRAPHIC INFORMATION SYSTEM IN THE SPATIAL ANALYSIS OF URBAN TRAFFIC ACCIDENTS IN CASCAVEL, PARANÁ, BRAZIL*

Letícia Ellen Dal’ Canton, Tamara Cantú Maltauro, Weverton Rodrigo Verica, Kleberson Rodrigo Nascimento, Erivelto Mercante, Luciana Pagliosa Carvalho Guedes

Abstract: considering the high rates of traffic accidents, care provided to victims must be fast and efficient. The objective was to analyze the density of traffic accidents and the profile of the victims assisted by the 4th Fire Department in Cascavel. It was also intended to analyze traffic signs and a place to build a new Fire Station. Geographic Information System and geoprocessing resources were used to identify the traffic accidents hotspots applying kernel density estimation. The victims’ profile and their association with the severity of the injuries were obtained based on the chi-square statistic and the correspondence analysis. Field data were investigated to verify traffic signs at accident locations that involved victims with severity of more serious injuries. Most accidents occurred in the afternoon, involving men between 18 and 30 years old. Running over was the occurrence that most stood out considering the severity of the victims, with locations without any traffic signs. Moreover, a plot that meets all the requested criteria and is located in a region of high occurrences of traffic accidents was found to build the new station.

Keywords: Multivariate analysis. Fire Department. Kernel density estimation. Geoprocessing.

SISTEMA DE INFORMAÇÃO GEOGRÁFICA NA ANÁLISE ESPACIAL DE ACIDENTES DE TRÂNSITO URBANO EM CASCAVEL, PARANÁ, BRASIL

Resumo: considerando os elevados índices de acidentes de trânsito, o atendimento proporcionado às vítimas deve ser rápido e eficiente. Objetivou-se analisar a densidade dos acidentes de trânsito e o perfil das vítimas atendidas pelo 4º Grupamento de Bombeiros em Cascavel. Teve-se ainda como intuito analisar a sinalização de trânsito e um local para construção de uma nova base para o 4º GB. Utilizou-se recursos de Sistema de Informação Geográfica e de geoprocessamento para identificar a incidência dos acidentes de trânsito aplicando a estimativa de densidade kernel. O perfil das vítimas e a associação deste com a gravidade das lesões foram
obtidos com base na estatística qui-quadrado e na análise de correspondência. Foram coletados dados de campo para verificar a sinalização de trânsito nos locais de acidentes que envolveram vítimas com grvidades de lesões mais graves. A maioria dos acidentes ocorreram a tarde, envolvendo homens entre 18 e 30 anos. O atropelamento foi o tipo de ocorrência que mais se destacou considerando a gravidade das vítimas, com locais sem qualquer tipo de sinalização de trânsito. Além disso, encontrou-se um terreno que atende aos critérios solicitados e localiza-se em uma região de elevadas ocorrências de acidentes de trânsito para construir a nova base.


SISTEMA DE INFORMAÇÃO GEOGRÁFICA EM ANÁLISE ESPACIAL DE ACIDENTES DE TRÁFICO URBANO EM CASCAVEL, PARANÁ, BRASIL

Resumen: considerando las altas tasas de los accidentes de tránsito, la asistencia brindada a las víctimas debe ser rápida y eficiente. El objetivo fue analizar la densidad de accidentes de tránsito y el perfil de las víctimas atendidas por el 4° Grupo de Bomberos en Cascavel. También estaba destinado a analizar las señales de tráfico y un lugar para construir una nueva base para el 4° GB. El Sistema de Información Geográfica y los recursos de geoprocessamiento se utilizaron para identificar la incidencia de los accidentes de tráfico utilizando la estimación de densidad del núcleo. El perfil de las víctimas y sus ocaciones con la gravedad de las lesiones se obtuvieron con base en estadísticas de chi-cuadrado y el análisis de correspondencia. Se recolectaron datos de campo para verificar las señales de tráfico en los sitios de accidentes que involucraron a victimas con gravedad de lesiones más graves. La mayoría de los accidentes ocurrieron en la tarde, involucrando hombres entre 18 y 30 años. Ser atropellado fue el tipo de ocurrencia que más se destaca encontrando la gravedad de las víctimas, con ubicaciones sin ningún tipo de señales de tráfico. Además, encontró un terreno que cumple con los criterios solicitados y está ubicado en una región de accidentes de alto tráfico para construir la nueva base.

Palabras clave: Análisis multivariante. Cuerpo de Bomberos. Estimación de densidad del kernel. Geoprocessamiento

The Geographic Information System (GIS) is based on a range of tools whose purpose is to acquire, store, retrieve, transform, and measure spatial information. Such geographical information portrays real-world objects in terms of positioning, their attributes and existing topological relationships (DABHADE; KAL; GEDAM, 2015).

GIS can be applied to a wide range of fields, such as the environmental disasters, sustainable energy, endemic control, agriculture, health, urban planning, demographic survey, and traffic (CHINGOMBE et al., 2015; CRISTEA, JOCEA, 2015; YASOBANT et al., 2015; ABDELRAHMAN, NATARAJAN, HEGDE, 2016; GUPTA et al., 2016; HASHIMOTO et al., 2016; JEMAL, AL-THUKAIR, 2016; NORTH, MILLER, 2017). Regarding traffic, the most important are research on accidents and route optimization (IVAN et al., 2015; ELSHEIKH et al., 2016).

Thus, tools using GIS can be applied to manage and process local information (ELSHEIKH et al., 2016). GIS makes it possible to gather all this data quickly and enables users to efficiently analyze and visualize information through map generation (PULUGURTHA; KRISHNAKUMAR; NAMBISAN, 2007).

The use of GIS can contribute to the treatment of the large database of the governmental organization 4th Fire Department of Paraná, whose scope includes, in the major-
ity, cities of the western region of the State. From the spatial knowledge of the action of this institution, the development of a traffic accident management system using GIS aims to improve the efficiency of preventive measures (JAYAN; GANESHKUMAR, 2010).

The new System of Record of Occurrences and Statistics of the Fire Department (SysBM), developed by the Information Technology team of the 4th Fire Department (4th FD), has been in operation since August 2017. This system aims to improve service and response to occurrences, georeferencing them, delineating the itinerary online, and integrating it with other internal public use systems (CORPO DE BOMBEIROS DE CASCAVEL, 2018).

Fire Department actions are broad, providing services to victims of fires, accidents with motor vehicles and motorcycles, running over, drowning, as well as performing pre-hospital and civil defense care. Moreover, integrated with the Fire Department is the Integrated Service to Assist Trauma in Emergency (SIATE), whose service is directed to the urgent care of victims. According to information from the Cascavel Fire Department portal, about 70% of SIATE’s visits are related to traffic accidents, such as running over, collisions, rollovers, and falls from vehicles (CORPO DE BOMBEIROS DE CASCAVEL, 2018).

Some factors are highlighted in the literature as determinants of the origin and severity of traffic accidents. Among them, besides the inadequate traffic sign, are age, gender, socioeconomic conditions, and high-risk behavioral factors such as driving after drinking alcoholic beverages and speeding are often cited (SIAGIAN et al., 2014; ULINSKI et al., 2016).

Occurrences of traffic accidents are rarely random in space and time. In most cases, traffic accidents form clusters (known as hotspots) in geographic space. Thus, it is essential to know how, where and when the accidents occurred and which social groups are vulnerable in order to help competent authorities to identify areas of risk and take effective measures to reduce the number of occurrences (IVAN et al., 2015; BENEDEK, CIOBANU, MAN, 2016). Therefore, the analysis of traffic accidents is one of the most important elements to improve traffic safety policies.

The aim of this study was, firstly, to carry out a study on traffic occurrences and obtain a profile of victims assisted by the 4th Fire Department in Cascavel. And with that, visualize how, where and when the traffic accidents occurred. Based on the severity of occurrences, it was analyzed whether there is an association between the places of records and possible inadequate traffic signs. In addition, considering the spatial analysis of the accidents and the restrictions imposed by officers from the 4th FD, was intended to be determined the best location to build a new Fire Station in Cascavel.

MATERIAL AND METHODS

The municipality chosen as the study area was Cascavel, located in the west of the State of Paraná, Brazil, at the latitude 24°57′ S and longitude 53°27′ W, with an altitude of around 800 meters (Figure 1). This locality covers an area of 2091.401 km², with a population density of 155.15 inhabitants/km² (IPARDES, 2018).
Cascavel has five Fire Department Stations, one of them only to assist the airport. The data related to the care of victims of traffic accidents from August 1, 2017, to August 31, 2018, was used. Traffic accidents include running over, rollover, crash with stationary obstruction, pileup, collision, falls from vehicles, run-off-road, and tipping.

The data were obtained from the SysBM platform, in which the Military Firefighter Organization (OBM) (4th FD), the fraction and municipalities covered by OBM (Cascavel-PR), and the nature of occurrence (traffic accident) were filtered. However, this system publicly provides only the data from the last 30 days and the 4th Fire Department of Cascavel granted the information on traffic accidents during the analyzed period.

The chi-square test at 5% statistical significance was used to associate the victims of traffic accidents according to sex (female and male) with age (≤10, 11–17, 18–30, 31–50, and ≥51 years old), period in which the occurrence was recorded (morning: from 6 to 11:59 am, afternoon: from 12 to 5:59 pm, evening: from 6 to 11:59 pm, and dawn: from 0 to 5:59 am), type of occurrence (running over, rollover, crash with obstruction, pileup, collision, falls from vehicles, run-off-road, and tipping), means of transport (car, bicycle, cart, truck, pedestrian, bus, and tractor), and injury severity (uninjured, mild, serious non-life-threatening, serious life-threatening, and death).

Some transit occurrences had no geographic coordinates or errors in their presentation. Thus, these records were excluded from making maps according to severity and density of records in the urban area of the municipality.
Record density map was obtained from kernel density estimation (KDE), which is a statistical method that uses techniques of the hotspots of point-events to predict the incidence in the vicinity (ZAMBOM; DIAS, 2013), and is given by Xie and Yan (2008):

$$\lambda(s) = \sum_{i=1}^{n} \frac{1}{r} k\left(\frac{d_{is}}{r}\right)$$

where $\lambda(s)$ is the density at location $s$, $r$ is the search radius (bandwidth) of the KDE (only points within $r$ are used to estimate $\lambda(s)$), $k\left(\frac{d_{is}}{r}\right)$ is the weight of a point $i$ at distance $d_{is}$ to location $s$. Thus, density map presents, by means of interpolation methods, the punctual intensity of the occurrences of traffic accidents throughout the study region. Types of occurrences of traffic accidents associated with the severity of injuries were also analyzed. The occurrence data that simultaneously presented a higher frequency of victims with serious injuries or death and lower frequency of uninjured victims were used to associate severity with sex, age, period, means of transport, and position. In both cases, the chi-square test with 5% significance was used for the association analysis, or equivalently Fisher’s exact test for the situation in which one of the variables presented a counting lower than 5 in any category (CONTADOR; SENNE, 2016). An extension of Fisher’s exact test was used for cases in which one of the associated variables had a number higher than two categories.

The correspondence analysis was performed for each pair of variables that presented significant association, as well as the number of categories higher than two, to graphically visualize the simultaneous relationship between the categories of these variables. This analysis shows that the closer the categories of the same variable are, or between variables, the more related these categories. Proximity is mainly analyzed in relation to the axis with a higher percentage of explicability. The axes are called “Dim 1” and “Dim 2”, with their percentages shown in parentheses (HÄRDLE; SIMAR, 2015).

A field investigation was performed based on the data of occurrence, which concomitantly showed higher frequencies of serious injuries and lower uninjured victims, to observe the signs of urban roads regarding the presence of crosswalk and vehicle and pedestrian traffic lights in some selected places to cover different regions of the urban perimeter of the municipality of Cascavel.

The construction of a new Fire Station in Cascavel considered the restrictive criteria provided by officers of the 4th FD, as follows: plots located in the northern region of the municipality with a minimum of 1200 m² and maximum of 4000 m², minimum average slope, owned by the municipal government, and with access to highways and expressway streets. The purpose was to verify whether the results referring to a higher density of occurrences related to their severity is in accordance with the interest of the Fire Department in the northern region of the municipality.

Minimum average slope was calculated according to the digital elevation model (DEM) acquired by means of radar images from the ALOS PALSAR (L-band and HH polarization) platform, whose spatial resolution is 12.5 meters and it is in accordance with the scale used in this study, as it allows a higher detailing of the areas. The DEM from
a mosaic composed of three ALOS PALSAR scenes was used to cover the municipality of Cascavel. Radar images were acquired free from the Alaska Satellite Facility portal (ASF, 2018). The Geo Portal was used to obtain information regarding plot size restriction (GEOPORTAL DE CASCAVEL, 2018).

Map construction and kernel density estimation were performed using the software QGIS 2.18 (QGIS DEVELOPMENT TEAM, 2019). The statistical analyses were processed using the software R (R DEVELOPMENT CORE TEAM, 2019) with FactoMine R (LE; JOSSE; HUSSON, 2008) and stats packages (R DEVELOPMENT CORE TEAM, 2019).

RESULTS AND DISCUSSION

General Study of Traffic Occurrences

A total of 3744 victims of traffic accidents were attended by the 4th Fire Department of the municipality of Cascavel from August 1, 2017, to August 31, 2018. Among them, 2362 (63.09%) were male and 1382 (36.91%) were female. Except for age, all other variables were statistically associated with sex (p-value <0.05) (Figure 2). Most of the victims were between 18 and 30 years of age, both for female (596; 43.13%) and for male (1085; 45.94%) (Figure 2a). The profile of victims of traffic accidents in Cascavel corroborates that observed by Pinto et al. (2016) and Mendonça, Silva and Castro (2017) in different Brazilian regions, such as Mekonnen and Teshager (2014), Ciobanu and Benedek (2015) and Benedek, Ciobanu and Man (2016) in other countries.

Males showed a higher incidence of records in the afternoon (845; 35.77%) and evening (799; 33.83%), while females had a higher incidence in the afternoon (522; 37.77%) (Figure 2b). Both sexes had high rates of occurrences in the afternoon, probably due to a greater flow of vehicles and pedestrians between 12:00 and 6:00 pm, result similar to that of Mendonça, Silva and Castro (2017) and Ivan, Benedek and Ciobanu (2019).

The collision was the most common occurrence for both sexes, covering about 65% of cases in each (Figure 2c), a percentage similar to that found by Mendonça, Silva and Castro (2017).

The means of transport with a frequency lower than 20 for females and males were categorized as other. For this variable, the most frequent occurrences for females were between cars (399; 28.87%) and between car and motorcycle (378; 27.35%). Accidents involving only car or motorcycle accounted for about 14% of cases each for this sex (Figure 2d). For males, car-motorcycle accidents (836; 35.39%) presented the highest incidence (Figure 2d). In addition, occurrences comprising only car, motorcycle, or between cars added between 10 and 15% of cases each for males (Figure 2d).

Regarding the severity of injuries, most of the victims presented mild injuries both for females (952; 68.89%) and for males (1488; 60.88%) (Figure 2e).
Figure 2: Number of victims of traffic accidents according to sex for variables (a) age, (b) period, (c) type of occurrence, (d) mean of transport, and (e) severity of the injury

Considering the kernel density value, traffic accidents were mapped in the urban perimeter of Cascavel (Figure 3). It was possible to highlight some areas of increased risk, as observed by Erdogan et al. (2007) in Turkey, Benedek, Ciobanu and Man (2016) in Romania, and Shafabakhsh, Famili and Bahadori (2017) in Iran. Hotspots were highlighted in the central, southern (especially the neighborhoods Parque São Paulo, Santa Felicidade, Universitário, and Maria Luiza) and north regions (Interlagos, Floresta, Brasmaideira, Brasilia, and Periolo) (Figure 3). In addition, considering the severity of occurrences, these regions had a high number of records whose injuries of victims were serious, both non-life-threatening and life-threatening (Figure 4).
Figure 3: Density of traffic accidents according to the number of occurrences

Figure 4: Traffic accidents according to the severity of injuries in victims
Subsequently, the types of occurrence were proportionally related to the severity of injuries. Pileup, run-off-road, and tipping represented a small portion of victims of traffic accidents (Figure 2c), being then disregarded. The remaining occurrences showed a statistically significant association with the severity of injuries (p-value<0.001) (Table 1).

Correspondence analysis showed that collision had a higher relationship with victims who presented mild injuries. On the other hand, falls from vehicles presented a higher relationship with those who had serious non-life-threatening and mild injuries (Figure 5).

Figure 5: Correspondence analysis between the type of occurrence and the severity of injury in victims.

Running over, crash with stationary obstruction, and rollover indicated a similarity among them, exhibiting a higher association with victims whose injuries were serious and life-threatening (Figure 5). In addition, although with a low death incidence, these three types of occurrence had the highest percentages for this severity, corresponding to about 3% of cases each (Table 1).

<table>
<thead>
<tr>
<th>Type of occurrence</th>
<th>Death</th>
<th>Serious life-threatening</th>
<th>Serious non-life-threatening</th>
<th>Mild</th>
<th>Uninjured</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running over</td>
<td>8 (2.71%)</td>
<td>17 (5.76%)</td>
<td>85 (28.81%)</td>
<td>170 (57.63%)</td>
<td>15 (5.08%)</td>
<td></td>
</tr>
<tr>
<td>Rollover</td>
<td>4 (2.82%)</td>
<td>9 (6.34%)</td>
<td>28 (19.72%)</td>
<td>80 (56.34%)</td>
<td>21 (14.79%)</td>
<td></td>
</tr>
<tr>
<td>Crash with obstruction</td>
<td>3 (2.34%)</td>
<td>5 (3.91%)</td>
<td>44 (34.38%)</td>
<td>59 (46.09%)</td>
<td>17 (13.28%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Collision</td>
<td>18 (0.74%)</td>
<td>67 (2.74%)</td>
<td>547 (22.35%)</td>
<td>1604 (65.55%)</td>
<td>211 (8.62%)</td>
<td></td>
</tr>
<tr>
<td>Fall from vehicle</td>
<td>1 (0.15%)</td>
<td>11 (1.62%)</td>
<td>200 (66.62%)</td>
<td>453 (66.62%)</td>
<td>15 (2.21%)</td>
<td></td>
</tr>
</tbody>
</table>
Considering the traffic accidents in which victims presented serious life-threatening injuries, running over (5.76%) and rollover (6.34%) stood out more in percentage terms than the crash with stationary obstruction (3.91%) (Table 1). Thus, 28.81% of ran over victims had serious injuries that could result in sequelae, although they did not present life-threatening risks, while rollover victims had a percentage of 19.72% (Table 1).

Victims with mild injuries attended by firefighters showed similar percentages when compared to those whose accident was due to running over and rollover, with values around 57% each. On the other hand, when comparing the percentage of uninjured individuals, it was noted that the proportion of victims from rollovers (14.79%) who came out unharmed was approximately three times higher than those resulting from running over (5.08%) (Table 1).

Based on these findings, a more in-depth study was carried out on victims of traffic accidents from running over, relating them to injury severity (Table 2). In this sense, according to the World Health Organization, pedestrians are among a group of the most vulnerable transit users (WHO, 2013).

Table 2: Absolute frequency and percentage (in parenthesis) of variables according to the severity of injuries in victims of running over

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Death</th>
<th>Serious life-threatening</th>
<th>Serious non-life-threatening</th>
<th>Mild</th>
<th>Uninjured</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Feminine</td>
<td>1 (12.50%)</td>
<td>8 (47.06%)</td>
<td>28 (32.94%)</td>
<td>78 (45.88%)</td>
<td>2 (13.33%)</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>Masculine</td>
<td>7 (87.50%)</td>
<td>9 (52.94%)</td>
<td>57 (67.06%)</td>
<td>92 (54.12%)</td>
<td>13 (86.67%)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>10 or less</td>
<td>0 (0.00%)</td>
<td>1 (5.88%)</td>
<td>17 (20.00%)</td>
<td>32 (18.82%)</td>
<td>1 (6.67%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11–17</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>4 (4.71%)</td>
<td>22 (12.94%)</td>
<td>1 (6.67%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18–30</td>
<td>3 (37.50%)</td>
<td>3 (17.65%)</td>
<td>13 (15.29%)</td>
<td>47 (27.65%)</td>
<td>4 (26.67%)</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>31–50</td>
<td>4 (50.00%)</td>
<td>5 (29.41%)</td>
<td>18 (21.18%)</td>
<td>37 (21.76%)</td>
<td>6 (40.00%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>51 or more</td>
<td>1 (12.50%)</td>
<td>8 (47.06%)</td>
<td>33 (38.82%)</td>
<td>32 (18.82%)</td>
<td>3 (20.00%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morning</td>
<td>1 (12.50%)</td>
<td>2 (11.76%)</td>
<td>18 (21.18%)</td>
<td>34 (20.00%)</td>
<td>0 (0.00%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Afternoon</td>
<td>0 (0.00%)</td>
<td>3 (17.65%)</td>
<td>23 (27.06%)</td>
<td>63 (37.06%)</td>
<td>5 (33.33%)</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Evening</td>
<td>6 (75.00%)</td>
<td>12 (70.59%)</td>
<td>35 (41.18%)</td>
<td>43 (25.29%)</td>
<td>8 (53.33%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dawn</td>
<td>1 (12.50%)</td>
<td>0 (0.00%)</td>
<td>9 (10.59%)</td>
<td>30 (17.65%)</td>
<td>2 (13.33%)</td>
<td></td>
</tr>
</tbody>
</table>

continua...
Considering the severity of injuries in victims of running over, the highest incidences among the 295 victims were males for all severities, most of them at the age groups from 18 to 30, 31 to 50, and higher than 51 years (Table 2). In general, the highest number of running over was observed in the afternoon and evening due to a higher flow of vehicles and pedestrians (Table 2). In this case, the highest incidences occurred between car and pedestrian and most of the victims were pedestrians (Table 2). Also, pedestrians presented the most serious injuries, while most of the uninjured individuals were drivers (Table 2).

Except for the means of transport, all analyzed variables (sex, age, period, and position of victims in the accident) were significantly associated with severity (p-value<0.05) (Table 2). The correspondence analysis (Figure 6a) showed that individuals aged 51 years or older had a higher association with serious non-life-threatening injuries, while most of the uninjured victims were individuals between 31 and 50 years old. The other age groups had victims who showed a higher relationship with mild injuries. Afternoon and dawn were associated with mild injuries (Figure 6b). Regarding the position of victims, drivers were uninjured from the accident, while pedestrians were associated with other injuries (Figure 6c).
Six records were not georeferenced or had location errors when the map correlating the occurrence of running over and the severity of injuries in victims was being constructed. Thus, an estimation of the geographical coordinates of these occurrences was performed considering the address and references presented in the database (Figure 7).

Neighborhoods Centro, Santa Cruz, the region between Santa Felicidade and Universitário, Interlagos, Floresta, Brasília, and Brasmadeira stood out for the number of occurrences of running over (Figure 7). The last four neighborhoods are part of the northern region of Cascavel, which consolidates the need for implementing a Fire Station in this region.
Analysis of Traffic Signs on Running Over Occurrences

Among the 295 occurrences of running over in Cascavel, signaling was analyzed in 165 (55.93%) of crossroads, which correspond to 3 (37.5%) deaths, 8 (47.06%) serious life-threatening, 47 (55.29%) serious non-life-threatening, 101 (59.41%) mild, and 6 (40.00%) uninjured.

The central region of Cascavel, especially on Brasil Avenue, had crossings with crosswalks and vehicle and pedestrian traffic lights. However, the road was revitalized by the Integrated Development Plan of Cascavel, in which vertical and horizontal signs were implemented or improved. Also, Tancredo Neves Avenue, which borders the neighborhoods Pioneiros Catarinenses and Alto Alegre were revitalized, but field survey showed that the project is still under development and the road is without signaling in some crossroads (Figure 8).

Some locations with the occurrence of running over with no signaling showed no improvements that could be made regarding the installation of traffic lights or crosswalks because the records were not obtained at a crossroad, which suggests carelessness by pedestrians regarding the crossing point, usually close to bus stops.

The northern region, specifically in neighborhoods Brasília, Brasmadeira, Interlagos, and Floresta, where there is a high number of running over (Figure 7), had no crossing signaling in most records or presented only crosswalks (Figure 8), which may have contributed to the high number of running overs attended by the Fire Department in these localities.

![Figure 8: Types of traffic signs in places with the occurrence of running over](image)
Construction of the New Fire Station

Considering firstly the high density of traffic accidents in the northern region (hotspots in Figure 3), especially running over, where victims were more severely injured, which consequently leads to the need for prompt care. Secondly, the precarious or nonexistent traffic signs in this region. And finally, using the firefighters’ know-how in search of an increasingly effective service, it was proposed to set up a new 4th FD in the Interlagos neighborhood, which belongs to the northern region of Cascavel.

Four plots without building and with a size between 1200 m$^2$ and 4000 m$^2$ were selected in the northern region. The average slope of each plot was calculated and plots 1, 3, and 4 presented the lowest average slope values, being classified as soft wavy (3-8%) (SANTOS et al., 2013) (Figure 9). The access to highways and expressway streets were analyzed, and plot 4 presented the best location for building the new Fire Station of the 4th FD since it has access to highways PR 180, BR 467, and Brasil Avenue by an expressway street with easy access, the Piquiri Avenue.

![Figure 9: Slope map of Interlagos neighborhood with the location of possible plots for the construction of the new Fire Station of the 4th Fire Department](image)

Figure 10 shows the traffic accidents hotspots from Cascavel, active Fire Stations located in the urban area of the municipality, and new Fire Station proposed.
CONCLUSIONS

Most victims of traffic accidents attended by the 4th Fire Department in the municipality of Cascavel were male and aged between 18 and 30 years. The group that aggregates male and young adults should receive a higher emphasis on educational actions, thus increasing efficiency in preventing urban traffic accidents.

The central, southern, and northern regions of Cascavel need special mention due to a higher incidence of accidents. In addition, with the field survey problems were observed in traffic signs, especially in urban roads where there is no type of signaling. These findings can be used for future implementations of public safety measures, which could include an upgrade to urban signs.

Considering the regions with the highest occurrences of traffic accidents and the restrictions provided by the Fire Department, which involve the professionals' know-how regarding the assistance to victims, a location was established in the northern region of the municipality to install a new Fire Station.

The use of geoprocessing tools was efficient in the study of the problems proposed in this study. This is because the georeferencing of Fire Department services allowed an advance in the storage of the occurrence data, as well as better decision-making regarding the service performed and internal demands of the corporation.

Therefore, the obtained conclusions delimited more assertive actions to attend the occurrences of traffic accidents. In addition, they were able to guide future studies with GIS to model the best route in certain periods of higher vehicle circulation.
Acknowledgments

To the Graduate Program in Agricultural Engineering (PGEAGRI), State University of Western Paraná (Unioeste), 4th Fire Department of Cascavel, and Coordination for the Improvement of Higher Education Personnel (Capes) and the National Council for Scientific and Technological Development (CNPq) for the financial support.

Note
1 Other: aggregates categories in which the sum of frequencies according to severity was lower than or equal to 10.

REFERENCES


LETÍCIA ELLEN DAL’ CANTON
PhD student in Agricultural Engineering Program in State University of Western Paraná (Unioeste). Master degree in Agricultural Engineering Program on Unioeste. Graduated in Mathematics on Unioeste. E-mail: leticiacanton@hotmail.com

TAMARA CANTÚ MALTAURO
Currently a PhD student in the Postgraduate Program in Agricultural Engineering in the Unioeste. Master’s degree in Agricultural Engineering (Unioeste). Graduated in Mathematics in the Unioeste. E-mail: tamara_ma02@hotmail.com

WEVERTON RODRIGO VERICA
Master in Agricultural Engineering from the Postgraduate Program in Agricultural Engineering (Unioeste). Graduate in Mathematics from the Unioeste. E-mail: wevertonverica@hotmail.com

KLEBERSON RODRIGO NASCIMENTO
Doctorand Master in the Postgraduate Program in Agricultural Engineering from the Unioeste. Graduate in Environmental Engineering at the University of Cataratas Dynamic University (UDC). E-mail: kleberson.rnascimento@gmail.com

ERIVELTO MERCANTE
PhD from the Faculty of Agricultural Engineering of the Unicamp. Doctorand Master Program in Agricultural Engineering from the Unioeste. Master in Agricultural Engineering from the Unioeste. Graduate in Agricultural Engineering from the Unioeste. Professor at the Unioeste. E-mail: erivelto.mercante@unioeste.br

LUCIANA PAGLIOISA CARVALHO GUEDES
PhD from the Agronomic Statistics and Experimentation of the USP. Doctor Program from the Agricultural Engineering from the Unioeste. Master in Agricultural Engineering from the Unioeste. Graduate in Mathematics from the Unioeste. Professor at the Unioeste. E-mail: luciana.guedes@unioeste.br