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GIS BASED ANALYSIS OF PEDESTRIAN-VEHICLE CRASH HOTSPOTS AND IDENTIFYING UNSAFE TRANSIT ACCESS IN THE REGIONS OF MUNICIPALITY RUSE

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Abstract: *This paper presents a GIS approach to analise spatial data of pedestrian-vehicle crash sites for identification and marking of unsafe bus stops. Crash sites data is implemented in a GPS platform along with locations of bus stops to build visual mapping of distribution of traffic accidents in the regions of transit areas used by pedestrians. As recent studies show a strong link between pedestrian accidents and transit access, the bus stops near the hotspots are marked and ranked based on the severity of he road accidents in the area. ArcGis tool is used to generate a pedestrian-vehicle crash hot spots map. The proposed approach uses data from 10 years (2010 - 2020) from available public sources on traffic accidents with pedestrians for the region of municipality of Ruse.*

Keywords: *GIS, Spatial Analysis, Hotspots, Map, Traffic Accidents, Transit Access*

JEL Codes:

INTRODUCTION

The number of injured and killed on the roads of Bulgaria continues to grow daily. Road accidents are one of the serious problems of the Bulgarian healthcare, despite the efforts of the institutions at central and local level. On the territory of ODMVR - Ruse (Fig. 1) for the last 6 years the number of killed in road accidents is 114 or an average of 19 per year. The injured during this period are 2612 or an average of 435.3 injured per year, and the number of accidents - 2066 or an average of 344.3 accidents per year. In 2019, 19 people were killed in the district, which is equal to the average number killed for the period under review.

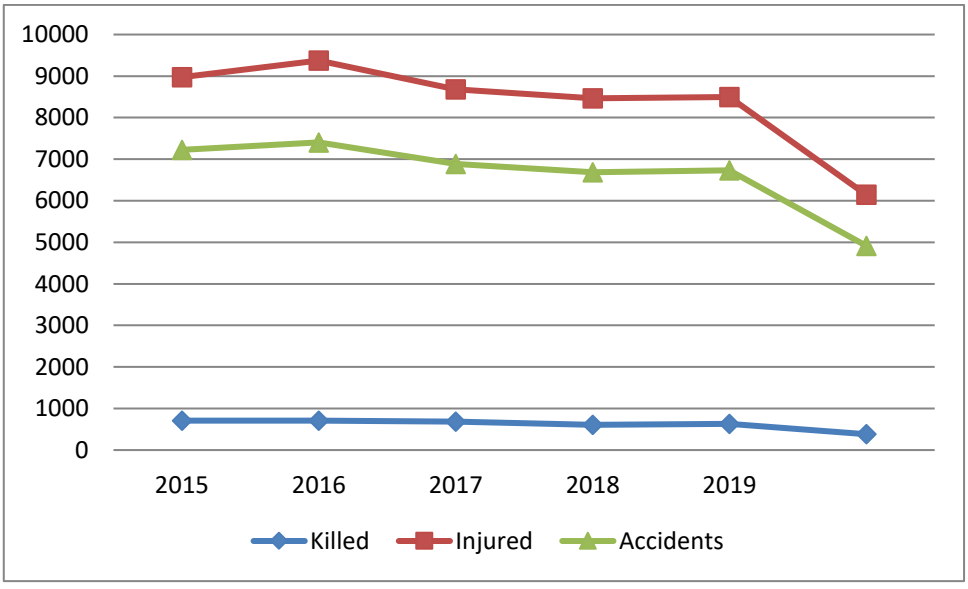

Fig. 1. Road traffic accidents, injured and killed in Ruse district for the period 2015-2020

During the same period in Bulgaria, 3718 people were killed in road accidents, or an average of 619 per year. In 2019, 628 people were killed, this shows an increase in the number of people killed by 1.5% compared to the average number for the tested period.

When comparing the number of people killed in the country and those in the district of Ruse, the following conclusion can be made: Of those killed in the country there is a tendency to increase (for 2019 1.5% more than their average number for the period 2015 - 2020), in Ruse there is no tendency to increase or decrease (for 2019 19 people, which is equal to their average number for the same period). Notwithstanding that account, in summary, the number of deaths during the examined period is considered decreasing, as shown in Figure 1.

It should be noted that a significant part of serious traffic accidents occur on the streets and boulevards in settlements and on municipal roads. Following the logic of the volume of passenger flows, it is assumed that the largest traffic from pedestrians is directed to public transport stops, mainly from the pedestrian zone [Grozev, D. 2019]. When effective measures are taken to reduce the number of injured and killed on the roads, it is of great importance to detect areas with a high concentration of accidents. One of the places that are critical for a city with such a volume of passenger traffic are the stops of urban passenger transport, which is one of he main reasons to explore this matter. The subject of the study is an accident with pedestrians that occurred in mediocre proximity to public transport stops.

EXPOSITION

Methodology for detection of sections with concentration of traffic accidents in the municipality of Rousse

The necessary information for the study includes a map of the urban road network (in gray in Fig. 2), a map of urban areas in the city, information about bus stops (marked in black in Fig. 4) and the location of accidents with pedestrians (marked in red in Fig.2.).

Accident information has been used for years (2015 - 2020), which is plotted on the map in the form of a GPS location. [ODMVR report - Ruse]. Accident location data is presented with GPS coordinates on the map, but not every accident in the respective years is available. For this reason, the results will be based on a mathematical sample.

Finding areas with a high concentration of accidents

When locating traffic accidents on a map, each point can be a single or multiple accident/s with a pedestrian. More than one accident can be reported in the same place or registered in mediocre proximity. Figure 2 shows a clustering model and identifies the main areas with a high concentration of accidents (in yellow). Marking these clusters helps to find where the relevant areas are on the city map. The author of the report [Tien T. L. (2011)] states that a severity index should be calculated to determine the size of hazardous areas. The index is obtained by formula (1), with the variables x1, x2, x3, x4, namely: the total number of participants, dead, injured and the number of accidents with property damage. In the analysis, the main properties that determine the size of each zone are the maximum values of these variables.

Without weighted data, it is difficult to understand the severity of any area.

$$SI = 3.X_1 + 1{,}8.X_2 + 1{,}3.X_3 + X_4 \quad (1)$$

where:

$X_1 =$ total number of people involved in an accident with a pedestrian;
$X_2 =$ the total number of people killed in a road accident with a pedestrian;
$X_3 =$ total number of injured in a road accident with a pedestrian;
$X_4 =$ total number of property damage accidents with pedestrians.

A map of the municipality of Rousse has been made on which the locations of road accidents with pedestrians and the respective areas with high concentration of road accidents are plotted.

Fig. .2. Distribution of the zones on the map of Rousse municipality

Figure 2 shows the surveyed areas of the urban road network and the corresponding dimensions of each zone showing their severity.

Table 1 Lists the first 13 areas with a higher weighting factor that will be subjected to statistical hotspot analysis.

Zone	accidents	participated	Injured	Killed	damage	weigxт
zone 13	9	21	12		7	63,6
zone 9	8	16	8		8	50,4
zone 11	8	16	8		7	50,4
zone 23	8	14	8		6	48,4
zone 8	6	12	6		6	37,8
zone 16	5	10	5		4	31,5
zone 18	5	9	4	1	4	31
zone 5	4	8	4		4	25,2
zone 14	4	8	4		4	25,2
zone 17	4	8	4		3	25,2
zone22	4	8	2		4	22,6
zone 25	4	8	4		3	25,2
zone 7	3	4	0	2	2	13,6

The first four zones with the largest dimensions stand out. Three of them are located in the area of Wide Center, Ruse: (Borisova Street, Nikolaevska Street, Serdika District next to the Pantheon) and the other in the area of Mall-Ruse, Lipnik Blvd. The map also shows 7 medium-sized areas. Of these, 3 zones stand out with higher weight located in the area of the Railway Station - Ruse, Bus Terminal East - Ruse and the roundabout to Hotel Riga. The other 4 medium-sized areas are located respectively in the areas of residential neighborhoods "Druzhba" № 2 and 3, industrial zone Ruse - West, extensions of Blvd. "Lipnik" and Razgrad highway Blvd. "Bulgaria".

Hotspot analysis of traffic accidents

Statistical hotspot analysis (Getis-Ord Gi *) is used to visualize the heat of each GPS location of a pedestrian accident. This method takes into account the set of weighted characteristics at each

location and identifies statistically significant hot and cold spots, namely the number of killed / injured, no. accident in a radius of 0,200 meters, no. participants in road accidents.

The identification of hotspots in road accidents is reliable and accurate, as it is performed with the help of well-designed spatial statistics, which take into account both the location of events at the points and their attributes. In Figure 3 we observe the results of the hotspot analysis located on the areas of accumulation of traffic accidents. Depicted are the so-called hot and cold areas, where the colors of the points determine the heat of the specific point location.

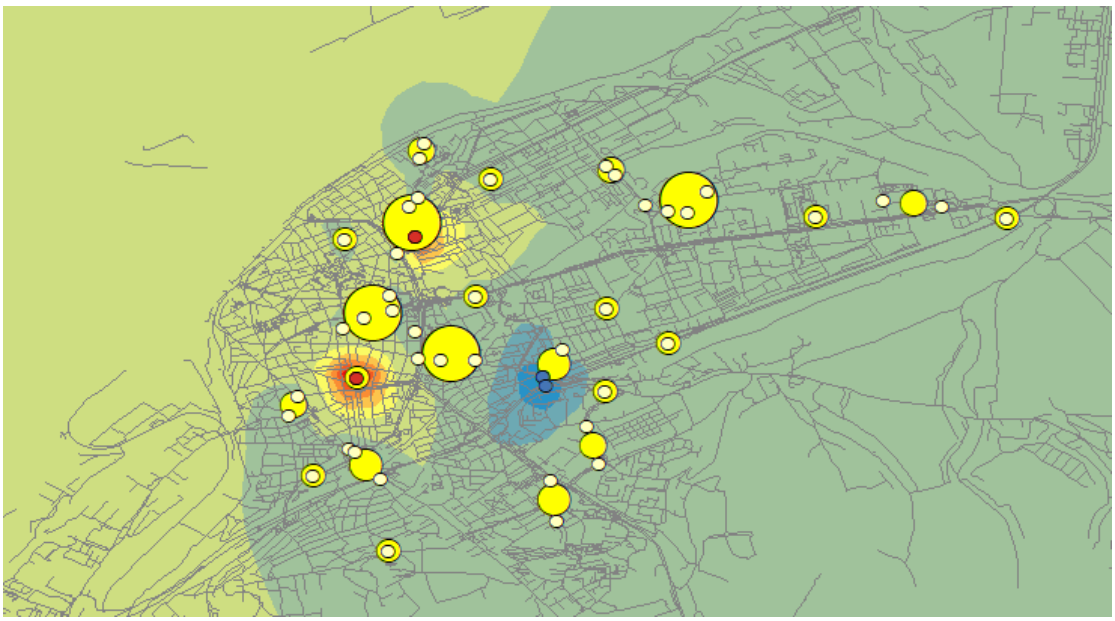

Fig. 3. Application of statistical tool for weighing back distance (IDW) for performing Hotspot analysis

The statistical instrument for backward weighing (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values of unknown points take into account the set of weighted characteristics at each location and identify statistically significant hot and cold points. This makes it easy to determine the degree of danger of each accident area.

Applying the locations of the stops from the city road network on the map of hot and cold zones.

After reporting the results of the tests conducted with the Hotspot analysis, a statistically significant model of clustering data on accidents with pedestrians is indicated, and the results of the hotspot analysis reveal hot spots in accidents with pedestrians in the municipality of Rousse. The hotspots are located near the crossroads of Serdika district in front of the Pantheon monument and on Borisova Street. (at the new connection with Hristo Botev Blvd) (Fig. 4). These intersections are located in two of the studied areas, namely:

- Zone 13 in the area of the Pantheon monument - where the following occurred in mediocre proximity: 9 accidents with a pedestrian in which 27 people were involved. Of these, 12 were injured, no one died, and 7 of the accidents were with property damage. This zone is in the first place by weight of the selected study areas (Table 1 in red).

- Zone 7 in the area of Borisova street also shows high heat levels. In contrast, this zone is not listed as the 13 highest severity zones. In mediocre proximity there were: 3 accidents with a pedestrian, in which 4 people were involved, no one was injured, two died, and 2 of the accidents were with property damage (Table 1 in red).

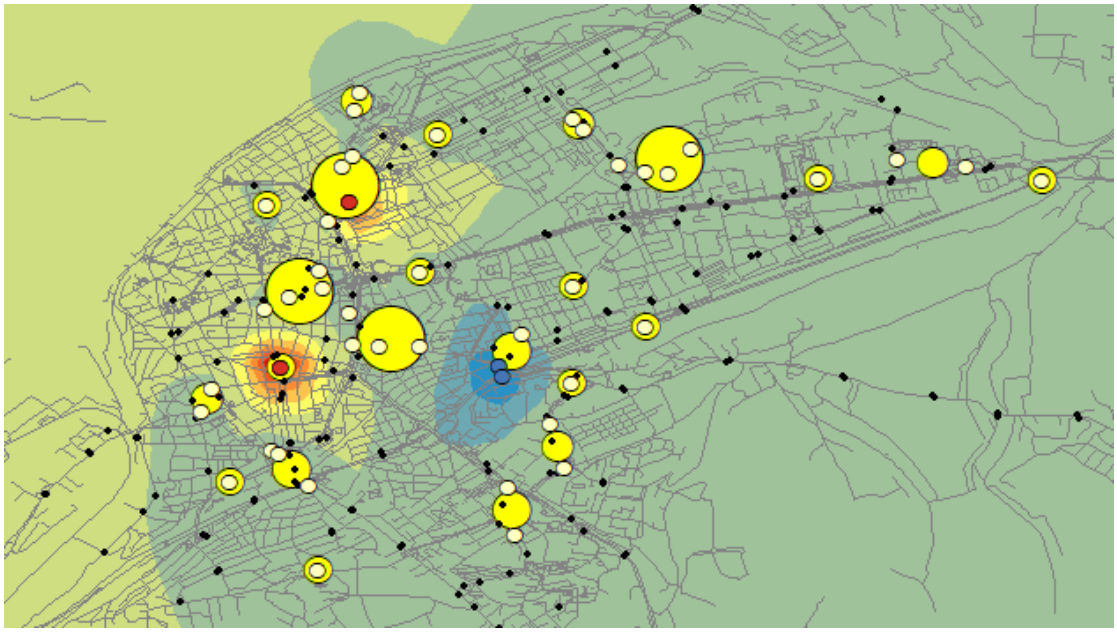

Fig. 4. Marking of the stops from the city road network on the hot and cold zones on the map of Rousse municipality

In order to mark the bus stops from the city road network on the hot and cold zones, it is necessary to place their metadata on the map of the municipality of Rousse, which has already been processed by tests.

From the received information 12 bus stops from the city network which are in mediocre proximity to a zone with high concentration of road accident with a pedestrian are taken out:

- stops: Maria Luisa, Orchid West, Pushkin, bl. Lermontov, Nekrasov are in the area of a wide center, between Borisova Street, Hristo Botev Blvd. and Ruse - East Industrial Zone. The high concentration of accidents around these stops may be due to the fact that they are located in an area where passenger flows and traffic conditions are congested and intersect. In the area of a wide center are some of the busiest neighborhoods of Ruse, where many business and sports complexes are also developed.
- Pantheon, Serdika, CBA - North, CBA - South, District Hospital, 3rd Polyclinic are in the area of the Pantheon monument and the continuation of Lipnik Boulevard. The high concentration of accidents around these stops may be due to the fact that they are located in the central part of Ruse. Again, passenger flows and road conditions are relatively congested and intersect. In these areas are the city center, the hospital, many developed business parks, recreational parks, and the only shopping complex outside the city center.

CONCLUSION

The analysis of most transport nodes in the cities in Bulgaria shows that the conditions for transit passage through them do not meet a number of requirements such as:

- The passage of traffic that flows through road junctions is not streamlined;

- Passenger paths intersect with transport flows of vehicles in conflict zones;

- Passengers are not protected from road accidents in conflict zones;

- The optimal technological requirements for operation of the pedestrian zones are not observed;

- There is not enough information about the locations of most pedestrian accidents to perform analyzes to prevent them.

The results from the analysis of data on accidents with pedestrians in Ruse show that the proposed approach can statistically detect spatial models of data on accidents and reasonably identify and classify dangerous bus stops in hotspots.

Hotspot identification is reliable and accurate, as it is performed using well-designed spatial statistics that take into account both the location of events at the points and their characteristics.

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