Geographia Technica, No. 2, 2012, pp. 32 to 38

THE SPATIO-TEMPORAL DISTRIBUTION OF ROAD ACCIDENTS IN CLUJ-NAPOCA

***Kinga IVAN*[1], *Ionel HAIDU*[1,2]**

ABSTRACT:
The spatio-temporal analysis of accidents derives from the necessity of emphasizing their spatial distribution, which offers the possibility of regulation and optimum control, as well as their tendency to be distributed in different moments in time (hours, days, seasons and years). The analysis of road accidents in Romania is very rarely tackled. The purpose of this present case study is to outline the manner in which road accidents are distributed in different moments in time, as well as their location in the city of Cluj-Napoca. From the total of 190 analyzed accidents, between the years 2010 and May 2012, these have registered higher values during daytime, during rush hours and during spring and autumn. In the analyzed time frame they have been distributed mostly along the backbone roads in the city, with a SW-NE directional tendency.

Key-words: *road accidents, GIS, spatial-temporal analysis, spatial distribution, Cluj-Napoca.*

1. INTRODUCTION

The rapid expansion of the number of vehicles in the last few years has lead to an increase of the vulnerability of the population towards road accidents. Road accidents have to pose a major preoccupation in Romania, due to the high number of deaths caused by these fore mentioned.

Out of the similar studies created on this topic we should mention the works elaborated by: *Scott*, *Warmerdam* (2005), *Erdogan* (2008), *Anderson* (2009); their preoccupation regarding the study of road accidents in traffic is quite recent. Studies with similar topics are very scarce in Romania, but realizing such a study is really necessary for enabling the creation of preventive measures by the local authorities.

The spatio-temporal analysis of road accidents has had as a main aim the identification of statistical relationships between the accidents and the moment of their occurrence in Cluj-Napoca. In the present study there are a few limitations regarding the exact cause of the accidents, the time span of the traffic blockage due to the accident or the direction in which the cars were moving at the time of the accident. By using integrated statistical analysis techniques in GIS, the time frames, days, months and years have been analyzed, as well as the way in which they were distributed in Cluj-Napoca. By means of spatial statistics the creation of a pertinent data analysis was possible, in order to evaluate the tendencies and relationships between the existing data.

The aim of the present study is to outline the importance and the efficiency of using GIS in collecting, processing and analyzing data. The Geographic Information System (GIS) is an efficient tool for displaying the spatial distribution of accidents along the road

1 *"Babeş-Bolyai" University, Fac. of Geography, Cluj-Napoca, Romania, ivan_kinga@yahoo.com.*
2 *Université de Lorraine-Metz, Laboratoire CEGUM, France, ionel.haidu@univ-lorraine.fr.*

network. GIS enables the rapid processing and display on the map of the information regarding accidents and it is useful in making decisions regarding the reduction and prevention of accidents, which should become a major preoccupation for local authorities.

2. DATA AND METHODS

The data regarding road accidents in Cluj-Napoca have been collected by the local media and transformed in digital format with the help of ArcMap 9.3 software. These data contain information regarding road accidents in the urban area, as well as the characteristics of the road network. They have been analyzed with the help of ArcView 3.2 software, through which a series of scripts have been implemented by *Lee J. and Wong W. S. D. (2001)*, ArcGis 9.3 and Microsoft Office Excel 2007.

In the present paper several types of data have been integrated in order to create a broad data base. The data regarding road accidents has been obtained for an observation time frame of two years and four months, from the year 2010 until May 2012.

In order to create such a broad database two sources of data have been used: spatial (satellite images) and descriptive. The spatial data source has been used in order to digitalize the street network inside the city and in order to locate in space the accidents which occurred in the observational time span, while the descriptive source has been used to create a table database.

The table database regarding the city's street network includes information regarding street denominations, width, length, estimated speed, the direction of the car, number of accidents occurred and number of victims for each street segment. Regarding the road accidents, the table database includes information on the date, time, day and month when they occurred and the number of victims.

In the graphic representation of the spatial data three geometric primitives have been used: points in the representations of the accident location, lines in representing the street network and polygons for administrative limitations.

3. SPATIAL DISTRIBUTION TREND OF ROAD ACCIDENTS

The manner in which road accidents are distributed inside the city can offer information regarding their directional tendency. To determine the directional tendency followed by the accidents in the observational time span, the standard derivational ellipse in the ArcGis 9.3 software has been employed.

The calculated derivational ellipse for the accident distribution has a clockwise rotation angle of 73,31° and follows a SW-NE direction. This direction corresponds to the backbone roads in the city, which are congested in the East-West direction. In **Fig. 1** one can see that the accidents are concentrated along the backbone roads and generally in the central area of the city.

The roads with a higher concentration regarding the number of accidents and victims are the ones connecting the city with other cities, such as Huedin, Turda, Zalău and Gherla. The increased flow of pedestrians and the great number of intersections in the central area can explain the increased number of accidents in this area. Another area with a significant number of road accidents is that of the airport, due to the increased traffic of people in the area and the location of the airport on a backbone road, Traian Vuia Street.

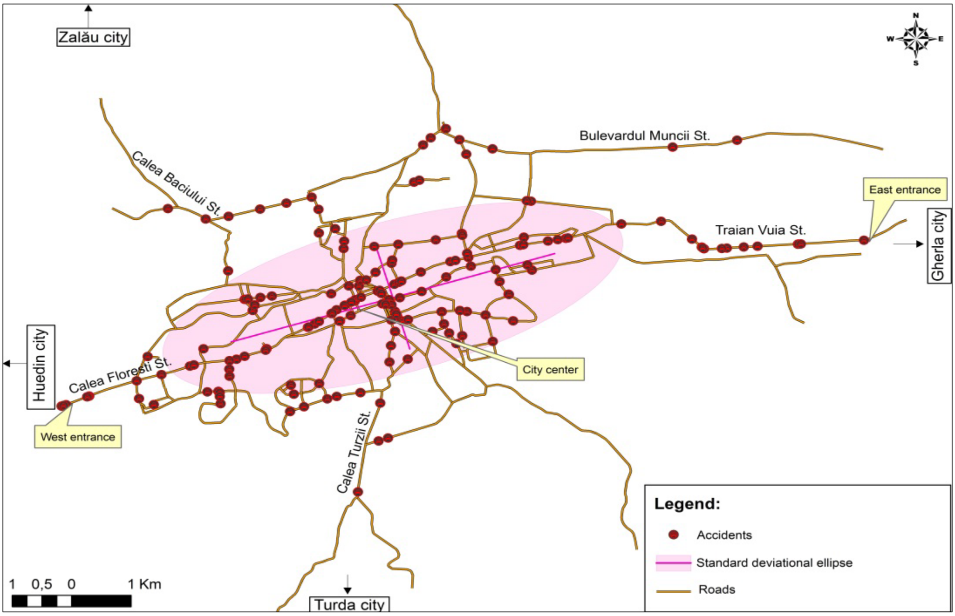

Fig. 1 Spatial distribution of road accident in Cluj-Napoca city.

The spatial distribution of the accidents follows in the majority of the cases a direction which corresponds to the backbone roads of the city, and the measures which can be implemented, in order to decrease their number along these arteries, could be the building of secondary roads that could become possible secondary routes for avoiding the highly circulated areas and at the same time the possibility of avoiding the occurrence of road accidents.

With the help of Kernel density the gravity of the accidents in the Cluj-Napoca has been established, on a radius of 500 m², depending on the number of the victims. The areas inside the observational areal, where the gravity of the accidents registered increased values correspond to the central area, Mărăşti district, Someşeni and Grigorescu. Once these areas with a high number of accidents have been established, the medical emergency units can assign sufficient personnel and the public institutions can make decisions in order to prevent these accidents from occurring.

The *HotSpot* Analysis has enabled the identification of spatial grouping of the high values (hot spots) and the lower ones (cold spots) regarding the number of the victims which occurred along the backbone roads of the city **(Fig. 2)**. This analysis offers a bird's eye view of the severity of the accidents occurred in the city.

The areas where the number of the victims has registered significant values are displayed with red dots on the map, and correspond to the backbone roads of the city where the traffic is increased, representing the exit and access to the city. The areal where the number of the victims has registered lower values are displayed in blue on the map and are situated in the city center. The decreased number of the victims resulting from these collisions is due to regulation infringement by the drivers, pedestrian negligence from people crossing the streets in unmarked areas, without causing a significant number of victims.

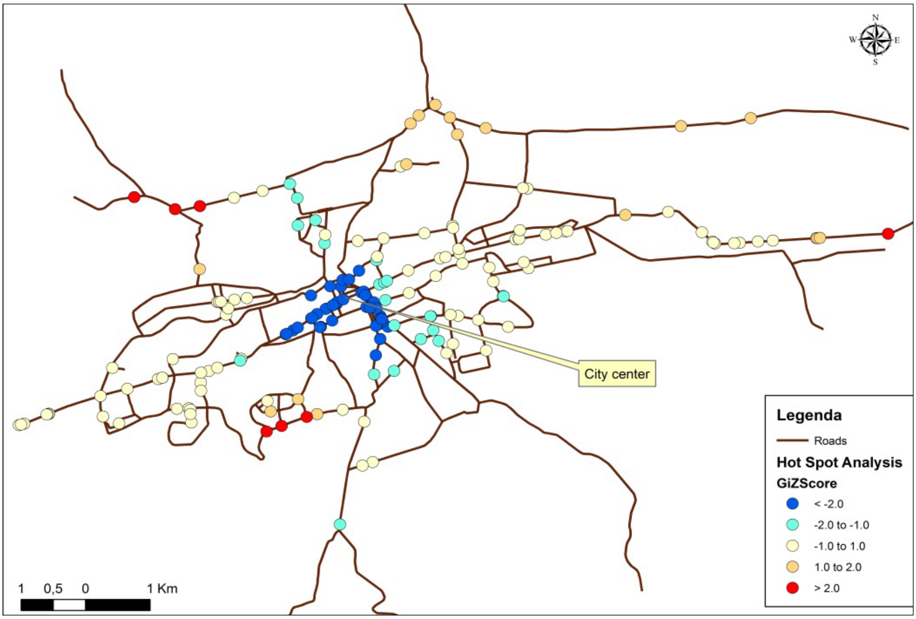

Fig. 2 Hot Spot Analysis in the case of road accidents victims.

4. SPATIO-TEMPORAL ANALYSIS OF ROAD ACCIDENTS

The distribution and the frequency of the road accidents vary depending on the moment of their occurrence: day or night, summer or winter, as well as the rush hour.

4.1. Day accidents analysis

In order to outline the mean center of the accidents occurred during daytime as they change from night, the mean center for an accident occurring during the day, respectively by night, in the study area, on the pair of coordinates (x,y) has been calculated automatically in ArcGis 9.3 software following the formula:

$$(\overline{X}mc, \overline{Y}mc) = \frac{\sum_{i=1}^{n} xi}{n}, \frac{\sum_{i=1}^{n} yi}{n} \quad (1)$$

Obtaining a mean center for the accidents occurring by day of X= 393226, Y=586731, and that of the accidents occurring by night of X= 392520, Y= 586600, one can notice that these two do not differ significantly. This piece of information can be used to enhance the manner in which the personnel is distributed in police stations and in emergency units in these two times of the day

The standard distance in the case of the road accidents occurred during the day, respectively during the night, has been calculated with the help of the script developed by *Lee J. and Wong W. S. D. (2001)* in the ArcView 3.2 software, in the basis of the formula:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(Xi - Xmc)^2 + \sum_{i=1}^{n}(Yi - Ymc)^2}{n}} \quad (2)$$

As a result of a histogram representation of the accident frequency corresponding to each day, as well as its analysis, important information regarding the shape of the distribution frequency have been obtained.

The distribution skewness, the way in which the number of the accidents is concentrated one way or the other from the mean has been automatically calculated with the help of ArcView 3.2 software, using one of the afore mentioned scripts, applying the formula:

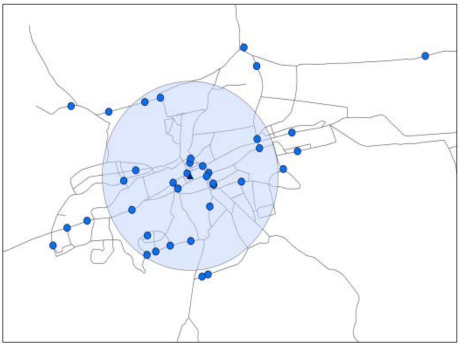

Fig. 3 Standard distance and mean center of the accidents during the night.

$$S = \frac{\sum (x - \bar{x})^3}{n\sigma^3} \tag{3}$$

A 0,4517 > 0 value of the skewness was obtained, which indicates a positive skewness, while the shape of the histogram is asymmetric to the left.

The degree of the distribution Kurtosis was calculated automatically also with the help of the above mentioned script, applying the formula:

$$K = \frac{\sum (x - \bar{x})^4}{n\sigma^4} \tag{4}$$

In the case of the distribution of the number of accidents occurred by day a -0.9096 < 3 value for the Kurtosis has been obtained, which indicates a flat distribution of the values, as each class contains a similar proportion of the number of accidents for each day.

The most significant number of accidents registered on Tuesdays (23 % out of the total), followed by Fridays (16 % out of the total), and the lowest number on Sundays (7 % out of the total). These results are explained by the fact that the traffic during the week is linked to the population circulation to the work place, which subsequently attracts a great number of accidents. Fridays, apart from the movement to the workplace, the population moves on greater distances, outside the city, in order to spend the weekend or to stock for the next week. Sundays are usually spent at home relaxing before going back to work, the next day.

The analysis of accidents on hourly intervals has outlined a rush hour at the beginning of the day between 8:00-10:59 in the morning, when the population goes to work and the students to school, a constant number of accidents occurring at 12:00 when the students get back from school and in the afternoon at about 14:00-16:59, when the population comes back from work. A rush hour in the evening, which happens to be the most significant of the day, is between 18:00-20:59, when the population goes shopping and to stock for several days. After this hour a regression of the number of night accidents occurs.

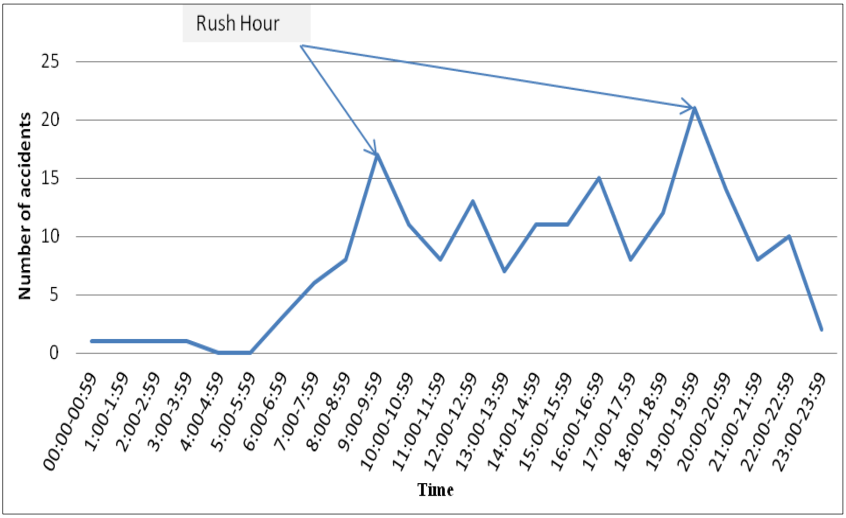

Fig.4 Statistic analysis of road accidents on hourly intervals.

In order to establish if these rush hours of the accidents correspond to the rush hours in traffic, the standard deviation from the mean per hour was calculated. During rush hours in traffic the deviations were positive, which proves that there were more accidents during rush hours than the mean number of accidents per hour.

Beside rush hours, the deviations were negative and they corresponded to the intervals during the night and the number of accidents was below the mean value of the accidents per hour. The number of the accidents during rush hours was greater than those outside rush hours, which proves that out of the total number of occurred accidents, the majority took place at rush hours in traffic.

4.2. Monthly analysis of road accidents

The frequency of the accidents for each month of the observational time frame outlines an increase of the accidents during spring and autumn. This increase of the number of accidents can be due to the lack of preventing driving, failing to adapt the speed to the condition of the road, which can lead to the skidding of the car during rainy periods in these two seasons.

From the total number of registered accidents, 29% occurred during spring, 25% during summer, 28% during autumn and 19% during winter. The lowest percentage of registered accidents in winter is probably due to the fact that the population uses public transport in order to prevent accidents. During this season, because of the weather difficulties, the population is more preventive.

5. CONCLUSIONS

The spatial distribution of road accidents has registered a directional tendency along the backbone roads in traffic. The most obvious directional tendency is on the East-West backbone road, Traian Vuia-Calea Floresti, which represents exit-access points in the city. Knowing this tendency for a larger time span is efficient for taking preventive measures in the future.

The spatio-temporal analysis of accidents has outlined a high number of accidents at the beginning of the week (on Tuesdays 23 % from the total), a tendency of grouping during the night justified by a smaller standard distance of the circle for night accidents rather than day ones, a greater number of accidents during rush hour when there is a positive standard deviation from the mean, a greater number of accidents in spring and autumn rather than in winter.

The spatial location of the accidents has enabled the identification of the areas where road accidents have the tendency to group (central area), where their gravity is (Mărăşti district, Someşeni and Grigorescu), as well as the identification of their cause. Identifying areals where the gravity of the accidents is higher can be useful to tourists or drivers when choosing safe routes and for authorities for establishing preventive and diminishing countermeasures.

REFERENCES

Anderson T., (2009), *Kernel Density Estimation and K-means Clustering to Profile Road Accident Hotspots*, Accident Analysis Prevention, 41, 359-364.

Erdogan E., Yilmaz I., Baybura T., Gullu M., (2008), *Geographical Information Systems Aided Traffic Accident Analysis System Case Study: City of Afyonkarahisar*, Accident Analysis Prevention, Vol. 40, Issue 1, 174-181.

Lee J., Wong D.W.S., (2001), *Statistical Analysis with ArcView GIS,* John Wiley and Sons, New York.

Scott L, Warmerdam N, (2005), *Extend crime analysis with ArcGIS spatial statistics tools*. ArcUser Magazine, April-June [USA].