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EXPOSURE AND TRIGGERING FACTORS OF ROAD (UN-) SAFETY AND RISKS IN IAȘI MUNICIPALITY (ROMANIA)

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Abstract: Road accidents are among the leading factors of the general mortality and worldwide about 1.3 million of peoples die yearly in road car crash and between twenty and fifty million suffer different injuries. Romania tops the list in European statistics, with an increased mortality rate caused by road accidents. Overall, this great number of road accidents is caused mainly by the indiscipline of road users doubled by the poor quality of road infrastructure. Regionally, the distribution of road accidents on the Romanian territory is closely related to the presence of the large urban settlements, the road density and connectivity with points or sectors having high values of traffic. Locally, the concentration of accidents in some “black spots” (hotspots) may be influenced by the road geometry, by the complexity of traffic etc. Using GIS software (SAGA GIS, TNTmips etc.) to process a complex database of road accidents (2007-2011), the authors apply the kernel function with different bandwidth to create an expressive spatial pattern of road accidents in Iași municipality. The study focuses on the exposed road sectors and on the main triggering factors: not granting priority to pedestrians and to other vehicles, pedestrians’ illegal crossing, excessive speeding and drunk driving.

Keywords: *road accidents, kernel density estimation, spatial analysis, Iași municipality*

I. INTRODUCTION

Road accidents are among the leading factors of the general mortality and worldwide about 1.3 million of peoples die yearly in road car crash and between 20 and 50 million suffer different injuries (WHO, 2009). The frequency of road accidents increased together with the human mobility, but in many countries the vehicle fleet grew up and the traffic developed exponentially without the necessary road infrastructure. This creates high discrepancies in the spatial distribution of road accidents occurrence, injuries and fatalities. More than 90% of road fatalities

occur in the low-income and middle-income countries, which have no more than 48% of the world registered cars (WHO, 2011). The economic losses resulted from car crash accidents were estimated at \$500 billion, meaning 1-3% of the gross national product of the world countries. Recognizing the dimension of the problem, in March 2010, the United Nation General Assembly proclaimed the Decade of Action for Road Safety, aiming at reducing of about 50% the predicted injury and death toll by 2020. Creating and implementing a safe road system is a common target for scientists and authorities. This means studies and actions to understand the road risk through education and information, to accept the risk through adjustment and enforcement of road rules, to have compliant road users, with safe vehicles on safe roads and roadsides (Newton, 2008).

Romania is still far from this goal and an expressive picture of this situation can be obtained by comparing the road (un)safety in Romania and the average values of similar indicators in the European Union (Table 1).

Table 1 Road (un)safety indicators in the EU, Romania and Iași County (2011)
(Aggregated data from GIRP, NIS, DDLRV and Eurostat)

Indicator	EU av.	Romania		Iași County	
		Value	EURank	Value	RoRank
Passenger cars/1000 inhabitants	477	202	27	162	32
Road density (km/sq.km*100)	131.40	35.12	-	43.28	-
GDP per capita	25 200	6 870	26	4 291	23
Accidents (total)	1 115 253	29 456	10	1 072	4
Accidents /1,000,000 inhabitants	2212	1550	-	1 310	16
Accidents /GDP per capita (‰)	87.8	128	-	249	3
Accidents/1 000 passenger cars	4.64	6.81	1	9.09	-
Number of deaths	31 030	2 377	6	58	-
Relative road mortality (D/acc*100)	2.78	8.06	-	5.41	
Death/1 000 000 inhabitants	62	128.5	2	80.16	11
Death/1 000 000 passenger cars	131	555	1	492	-
Pedestrian as % of road fatalities	19.8	36.5	1		

These statistics resulted through combination and aggregation of data provided by the General Inspectorate of the Romanian Police (GIRP), the National Institute of Statistics, the Directorate for Driving License and Vehicle Registration (DDLVR) and Eurostat. It should be noted that some data vary from one source to another, but differences remain insignificant for the final synthesis.

In 2011, there were recorded 9290 severe road accidents with 2018 fatalities and 8768 seriously injured peoples (GIRP, 2012). Overall, this great

number of road accidents is caused mainly by the indiscipline of road users doubled by the poor quality of road infrastructure. Regionally, the distribution of road accidents on the Romanian territory is closely related to the presence of the large urban settlements, the road density and connectivity with points or sectors having high values of traffic. Locally, the concentration of accidents in some “black spots” (hotspots) may be influenced by the road geometry (e.g. sharp bends with poor visibility) or by the complexity of traffic (pedestrian crossing, intersection with road without priority), by sectors with intense traffic and possibility to increase rapidly the running speed (e.g. to out of town) or other sectors of modern road that allow or just tempt the high speed driving (straight road sections, apparently without obstacles).

Thorough the country, the road (insecurity) vary greatly depending especially on the road density, the road flow and the number of the registered cars. In this hierarchy, Iași County tops the specific indicators shown in table 1. In terms of absolute values, in 2011, there were recorded 1 072 road accidents, 350 of them being considered severe accidents (causing human deaths and/or serious physical injuries). These accidents killed 58 peoples and injured other 1289 ones (351 of them being severely injured). According to the Iași County Police Inspectorate (2012), the main causes were: pedestrians’ illegal crossing (21%), excessive speeding for road conditions (16%), not granting priority to pedestrians (12%), misconducts of bicyclists (10%), not granting priority to vehicles (7%), pedestrians on the carriageway (7%), unsafe distance between vehicles (5%), drunk driving (5%) etc.

The pure statistics are not always enough expressive by itself: some causes are related to drivers, other to cars or roads, but the impact often varies depending on how these factors are interacting in specific moments and in precise road sectors. Furthermore, causes and consequences are quite different whether accidents occur outside localities or within their borders (especially within towns, but also within villages along the main roads).

Our study focuses on the county town, Iași, which is also the largest city from Eastern Romania (290 422 in 2011, meaning 37.6% of the total county population and 81.2% of the urban county population) and with an intense road traffic increased even more by its attractiveness as academic, medical and religious center. As in any great city, the road traffic is more complex, due to the complicate road network, rapid alternation of roads with different ranks, road intersections, pedestrian crossings, public transport etc. In these conditions, the intense traffic with clear peak hours, crowded streets and residential areas with specific road rules change the profile and the spatial pattern of road accidents.

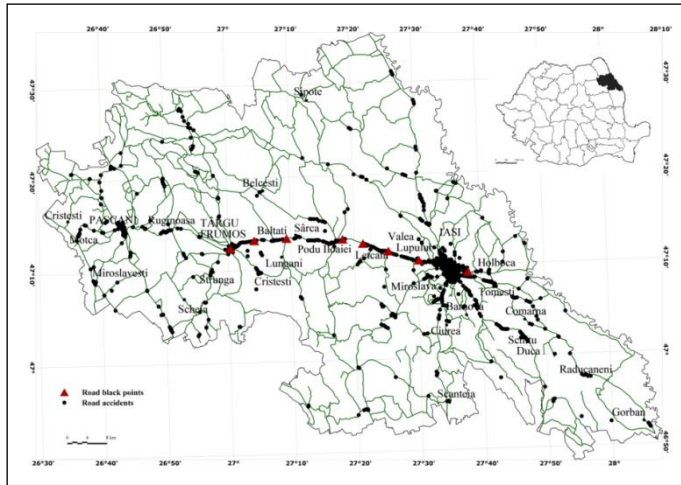


Fig. 1 Road network and black points within Iași County. Location of study area

II. DATA AND METHODS

Scientific approaches regarding the road risks and safety vary greatly in disciplinary context and largely depend on the scale and the level of analysis. Many scientific approaches about the road accidents on Romanian roads focus on the psychometric analysis of driving and drivers (Lotrean et al., 2011; Gheorghiu and Hăvârneanu, 2012; Danciu et al., 2012; Iliescu and Sărbescu, 2013) or on the medical perspectives of injuries and fatalities (Benea and Dumitrașcu, 2010), while other studies resume to statistics at county level (Călinoiu et al., 2012). There are only few studies regarding the spatial distribution of road accidents, of their causes and effects, both at country level and at local level (Ivan and Haidu, 2012; Ancuța and Muțulescu, 2012; Stângă, 2013).

To realize this study, we created a complex database starting from the police press releases and other newspaper articles. Unfortunately, it was impossible to obtain official information from the Traffic and Accidents Database of the Romanian Police, although these should be publically available. For this reason, we state from the beginning that our own database is far from being complete, but it is more than a simple sample and it allows creating the spatial pattern of road accidents and of their main causes in Iași municipality.

This database was initially created at county level to verify its representativeness and includes 1416 accidents that occurred between 2007 and 2011 in Iași county (about 28% of all road accidents and more than 65% of the severe accidents). The difference between these relative values results from the fact

that severe accidents draw attention of media and are almost every time presented in police press releases. Moreover, we ignored from the beginning the slight accidents (like dabs) without physical injuries or significant damages. However, these percentages increase together with the increasing transparency and improving access to information (Table 2). For 2007-2008, the total number of road accidents indicated in table 2 was computed by the authors based on partial statistics and trimestral police reports, while for 2009-2010, it was provided by the Iași County Police Inspectorate.

Table 2 Representativeness of the DS* road accidents database

Year	Road accidents occurred in Iași county (total)	Road accidents in DS* database	
		Number	% of total
2007	900**	202	22.44
2008	880**	207	23.52
2009	1096***	281	25.64
2010	976***	313	32.07
2011	1072***	413	38.53
Total/average	4924**	1416	28.44

*Dicu and Stângă

For Iași municipality (fig. 2), the database includes 710 accidents that allow creating a suggestive spatial pattern of road insecurity (2007 – 101 accidents; 2008 – 103 accidents; 2009 – 127 accidents; 2010 – 170 accidents; 2011 – 209 accidents).

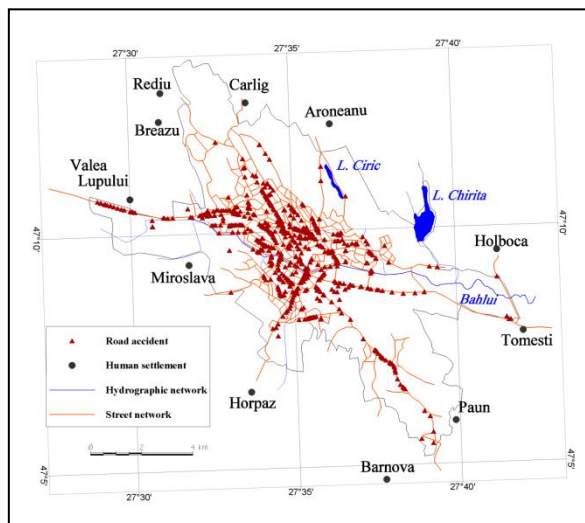


Fig. 2 Road accidents in Iași municipality between 2007 and 2011 (DS database)

The initial database file (.dbf) includes a large set of variables related to each road accident:

- identification information: date (year, month, day, hour) and location;
- type of accident (single vehicle crash, collision with another vehicle, involvement of public transportation vehicles, biker or bicyclist involvement, pedestrian impact, slippage etc.);
- main and aggravating causes of accidents;
- data on the driver considered/found guilty (age, gender etc.);
- data on the involved vehicle/vehicles (type and age etc.);
- property damage, casualties (injuries and fatalities).

The accidents were localized using Google Earth place mark option (Fig. 3), coded based on order numbers and archived as .kmz files (Keyhole Markup Language). The accuracy of road accidents positioning was enhanced by high resolution of satellite images for the urban area, by the Google Earth street option and by the great number of photos and helpful auxiliary details that are not available outside the town (buildings, bus stations, pedestrian crossing traffic lights etc.). Overall, the positioning errors remains under the minimum limit of the interpolation model and do not affect the final results.

These .dbf files were imported in the Global Mapper 10.02 software, the spatial configuration being adapted for the stereographic projection (Stereo 70, Krassovsky ellipsoid 1938/1940, Dealul Dealul Piscului). They were exported then as point vector ESRI shapefile, to whom the .dbf spreadsheet was attached using the TNTmips 7.3 software.

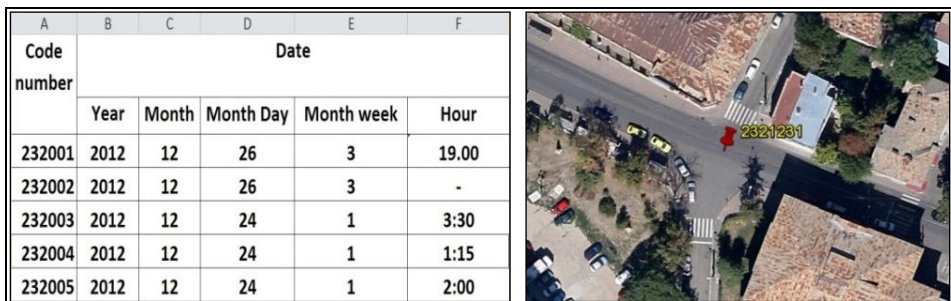


Fig. 3 Database aggregation (extract)

There are many tools, methods and technics to create the spatial pattern of a given set of events (including road accidents), but Kernel function is one of the most common methods used to transform a discrete set of data in a continuous output map containing the spatial density of those data (Fotheringham et al., 2000).

The method is implemented in several GIS softwares (including in SAGA GIS) that allow placing a smoothly shaped surface (kernel) over each point as shown in fig. 4. In this study, data processing was performed using both the TNTmips 7.3 and SAGA Gis softwares. For each kernel, the model applies a function described by the generalized equation:

$$f(x, y) = \frac{1}{nr^2} \sum_{i=1}^n k \frac{d_i}{r} \quad (\text{eq. 1}),$$

where:

- $f(x, y)$ is the density estimation in a point defined by the coordinates (x,y);
- n is the number of samples (events, observations etc.);
- r is a smoothing parameter (bandwidth) that control the width of the kernel;
- k is the kernel function that control the shape of the hump;
- d_i is the distance between the x, y defined location and the i^{th} observation.

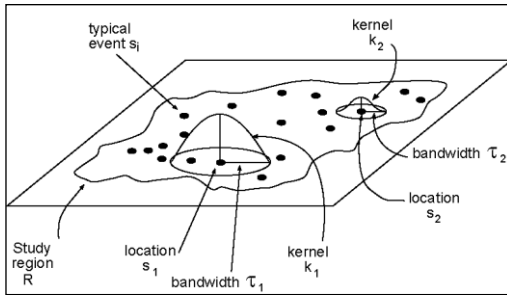


Fig. 4 Kernel density estimation principle (Bailey and Gatrell, 1995)

The results range from 1 at the location of the point and 0 at the kernel boundary. The value for each pixel is obtained by summing the values of all kernels that overlap at the pixel center, divided by the kernel area and the final map provides the sum of these results for each pixel where the individual kernels are overlapping (Bailey and Gatrell, 1995).

A suggestive 3D image based on our own data is shown in fig. 5.

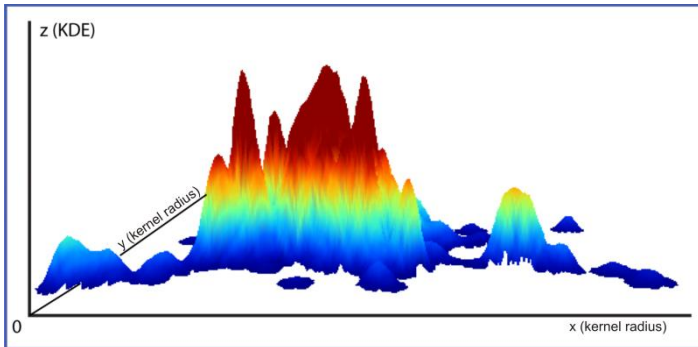


Fig. 5 3D image of kernel density estimation for road accidents in Iași municipality

There are several common kernel (Epanechnikov, quartic or biweight, triweight, Gaussian), but they are not too different from the point of view of their capacity to replicate the distribution shape (Silverman, 1986). SAGA GIS uses quartic or Gaussian kernel function. The last one is described by two equation (Xie and Yan, 2008):

$$k \frac{d_i}{r} = \frac{1}{2\pi} \exp -\frac{d_i^2}{2r^2}, \text{ when } 0 < d_i \leq r \quad (\text{eq. 2})$$

and

$$k \frac{d_i}{r} = 0, \text{ if } d_i > r. \quad (\text{eq. 3}).$$

Quartic function seems to be an easier choice in many software packages, but it is in fact only an approximation of the Gaussian function (Schabenberger and Gotway, 2005) and that is why we used the second one in this study. Selecting smaller or larger kernel radius or bandwidth allows emphasizing either the local or the regional context (Fotheringham et al. 2000).

III. RESULTS AND DISCUSSIONS

III.1. Exposure

The exposure can be defined as the characteristic of an individual or a group of individuals to be placed in any road sectors or regions with different frequencies of road accidents, no matter if they are related to the road geometry, to the high traffic flow or to the repeatability of any triggering factor. On road, there is always and everywhere a minimum risk and the exposure analysis aims at identifying those sectors more prone to road accidents due to the spatial correlation between distinct factors. In this purpose, the kernel density was calculated for different values of the bandwidth.

There are many techniques for data-based bandwidth selection, such as: successive free-hand tests, reference to standard distribution, Silverman's rule of thumb, least squares or bias cross validation, plug-in and smoothed bootstrap techniques etc. (Scott and Terrel, 1987; Taylor, 1989; Wand and Jones, 1993; Grund and Hall, 1995; Jones et al., 1996; Duong, 2007; Osemwenkhae and Ogbeide, 2010; Gannoun et al., 2010). In this study, we looked for a method easy to be applied in a geographical study. The successive free-hand tests remain subjective, although they require, however, an expert knowledge. The rule of thumb (based on the number of accidents and the standard deviation of their distribution) is the easiest mathematical method, but it is not suitable in this case since it assumes that the accidents (data) are normally distributed.

The best choice was to relate the results to a standard reference of road accidents location, more precisely to a statistical indicator that describes the point cloud (road accidents spatial dataset). Hence we calculated the standard deviation of point distribution (distances) and then we successively calculated kernel density for bandwidth values 1·StDev (132 m), 2·StDev (264 m) and 4·StDev (528 m), the most suggestive results being obtained for bandwidth values of 1·Stdev and 2·StDev. Obviously, the values of kernel density are different since a term of equation is changing; the maximum values range from 2.21 for $r = 66$ m and 3.64 for $r = 132$ m to 7.11 for $r = 264$ and 17.19 for $r = 528$.

As the value of bandwidth “ r ” is lower, its changing has a significant impact on the results, but the more it is higher, this impact becomes increasingly negligible. Furthermore, it should be noted that the ascending change of “ r ” implies a transition from punctual pattern to linear and, then, areal pattern, namely from hotspots to black roads and urban neighborhoods.

For bandwidth with values below 1·StDev, the maps are a little difficult to read and resemble quite well with the map of accidents distribution, although they emphasize the most dangerous traffic intersections. At bandwidth of 1·StDev (fig. 6), we pass from the punctual to linear pattern, being even better highlighted the aforementioned intersections, but also the main roads with a high frequency of road accidents and, implicitly, a high degree of exposure (fig. 6).

For this estimation ($r = 132$ m), kernel density values up to 3.64 and there are more than 15 sectors that tend to the maximum (>3.50): Red Bridge intersection; intersection between Socola and Primăverii boulevards; intersection of Nicolae Iorga Boulevard with Nicolina Street; Stone Pridge and Alexandru Bridge roundabout; intersection Tudor Vladimirescu-Chimiei; Bușinescu; Iron Bridge; Moara de Foc (crossroad of Păcurari Street with Muntenimii and Canta streets); Independenței Boulevard nearby „Gr. T. Popa University” (crossroad with Vasile Alecsandri street); Independenței – Carol I roundabout (Foundation area); Carol I Boulevard – Oastei Street junction (Supercopou area); Tg. Cucu (Independenței-Sărărie); Păcurari-Rediu intersection (roundabout); Alexandru cel Bun Boulevard, nearby Voievozilor Square; Arcu road (junctions with Gării and Bacinschi streets) etc. Most of this examples are intersections, but the context of accidents occurrence can be different: from complexe and agglomerate traffic of vehicles (Red Bridge), to pedestrian negligence (Supercopou) or speeding (Supercopou; the way out of town) and other causes.

The shape of the kernel density map is also suggestive from the directional point of view, showing the roads more prone to accidents, fact that become even more expressive changing the bandwidth to 2·StDev (fig. 7).

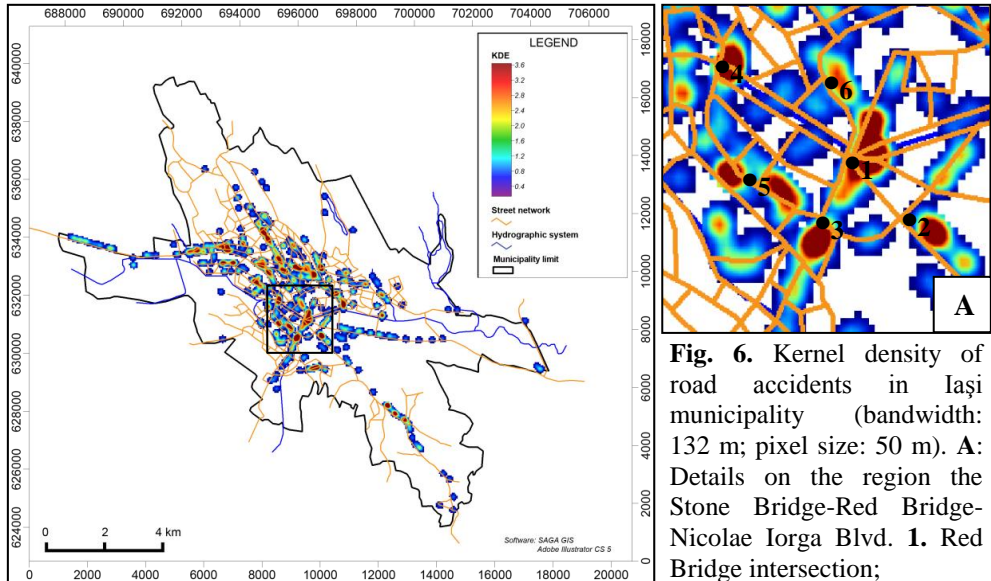


Fig. 6. Kernel density of road accidents in Iași municipality (bandwidth: 132 m; pixel size: 50 m). **A:** Details on the region the Stone Bridge-Red Bridge-Nicolae Iorga Blvd. **1.** Red Bridge intersection;

2. Intersection between Socola and Primăverii boulevards; **3.** Intersection Nicolae Iorga Boulevard - Nicolina Street; **4.** Stone Pridge; **5.** Nicolae Iorga Boulevard; **6.** Palat Street.

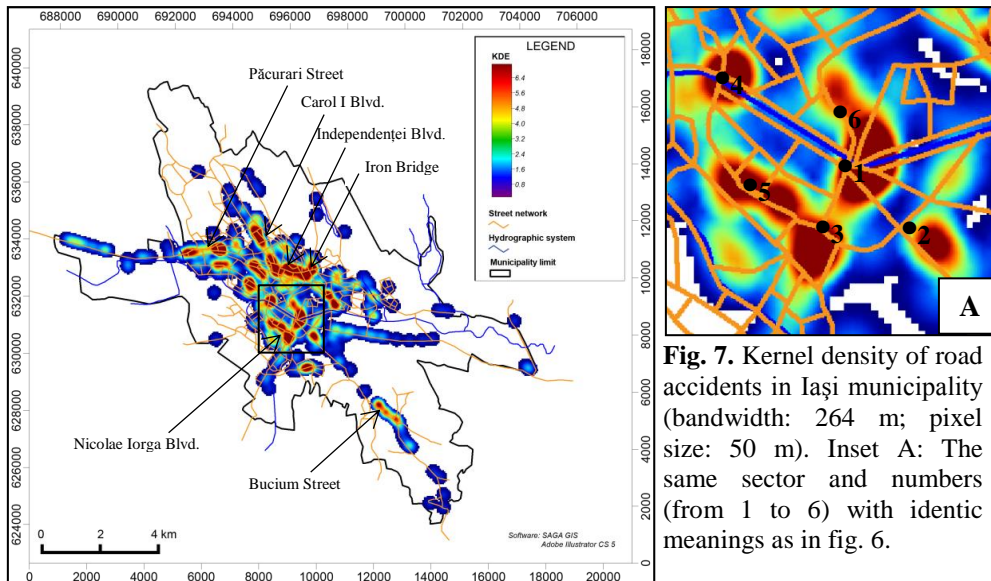


Fig. 7. Kernel density of road accidents in Iași municipality (bandwidth: 264 m; pixel size: 50 m). Inset **A:** The same sector and numbers (from 1 to 6) with identic meanings as in fig. 6.

We can easily track on the map the red roads from Iron Bridge to Independenței and Carol I boulevards or Păcurari, Nicolae Iorga and Bucium streets, with intense traffic and high frequency of accidents. These maps show in fact in which points and along which streets the authorities need to take supplementary measures to enhance road safety.

As the value of „r” increases, the areal pattern becomes almost exclusive at the expense of the punctual and linear ones. The map in fig. 8 rather reveals the most agglomerate areas: the largest one extends from the Iron Bridge, on the Independenței Boulevard and then till Carol I Boulevard (to the north) and the Railway Station to the south-west); the second one makes a loop from the Red Bridge through Nicolae Iorga Boulevard and Nicolina neighborhood till Stone Bridge and Alexandru Bridge roundabout;

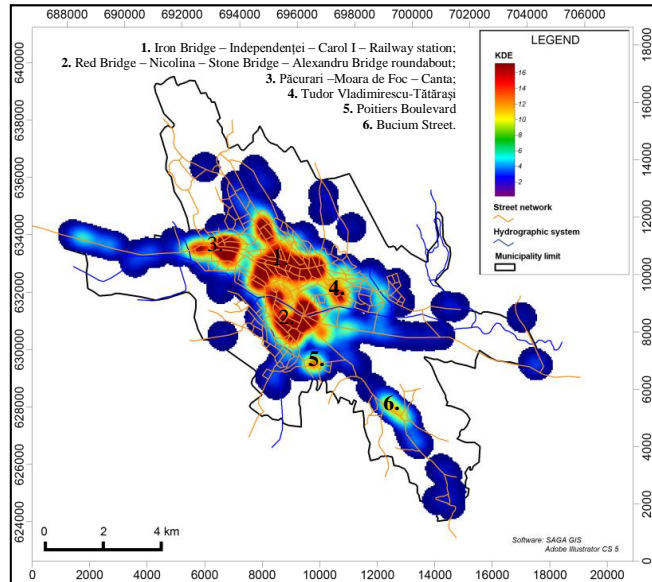


Fig. 8 Kernel density of road accidents in Iași municipality (bandwidth: 528 m; pixel size: 50 m)

Other areas, more limited, do not reach the maximum values (KDE remains below 16.0): Tudor Vladimirescu-Tătărași; Potiers Boulevard (Siraj area); Bucium Street etc. It is interesting to observe the discontinuity that appears between the first two areas because of the railway track that cut off the road traffic between the northern and the southern part of the town.

III.2. Triggering factors

Accidents occur in a context in which interact passive factors with catalysts and active or triggering factors. In the first category (passive factors), usually there are elements that describe the road: blind curve, improper carriageway condition, inappropriately signaled intersection etc. These elements need consistent proactive measures to be changed in better. Catalysts include a

wide range of factors related to: weather (rain and wet roads, glazed frost, fog etc.); traffic (crowded roads); vehicle conditions (technical failures or improper equipment); traffic participants (e.g. driving without a license) etc. Generally determined by the road users, the triggering factors act on the background created by the passive factors and their action can be enhanced by catalysts. It should be noticed that in some cases the first two categories of factors may be completely missing, while in other cases several triggering factors potentiate each other. Overall, this interaction, how it is done and how each factor participates determine the size and the typology of road accidents' consequences. That is why an exhaustive and comprehensive study should analyze the entire road system, including users, vehicles, roads and environment (Stigson et al., 2008)

In Iași municipality, according to our own database, the main triggering factors of road accidents are: not granting priority to pedestrians: 20.99%; not granting priority to vehicles: 18.17%; pedestrians' illegal crossing: 16.62%; excessive speeding for the road conditions: 15.07%; drunk driving: 7.32%.

These five causes are the main triggering factor for more than three quarters (78.17%) of the road accidents within Iași city. Other accidents are determined by: uninsured lane changing (3.66%); failure to comply with the distance between vehicles (3.24%); illegal overcoming (2.68%); driving on the opposite roadway (2.19%) and so on.

III.2.1. Pedestrian priority and illegal crossing

Globally, pedestrians represent about 22% of all traffic death, but in some countries this percentage may be double (in Romania, pedestrians are 36.5% of total fatalities). There are many approaches that focus on the causes that could explain this high incidence, including through statistical and spatial models that would improve the road safety management (Holland and Hill, 2007; Zegeer and Bushell, 2012; Prato and Gitelman, 2012).

Most of pedestrian are injured in urban areas, due to intense vehicle and pedestrian traffic. In Iași County, 78.44% of pedestrians were injured in urban areas, Iași town being the black leader of standing with more than four fifths of urban pedestrian injuries and two thirds of all pedestrian injuries (Table 3). In terms of fatalities, 59.49% of pedestrians were killed in urban areas, 24.05% only in Iași town. The fatality rate is lower the injury rate than outside the town due to the speed limits, the fatality rate being significantly related to the impact speed (Davis, 2001; Rosén et al., 2011).

Table 3. Pedestrian injuries and fatalities in Iași county and town

Indicator	Iași County		Iași Town
	Number	Number	%
Accidents	1416	710	50.14
Injuries	1521	879	57.79
Fatalities	209	45	21.53
Pedestrian injuries	Number	450	298
	% of injuries	29.59	-
Pedestrian fatalities	Number	79	19
	% of fatalities	37.80	-

Accidents that affect pedestrians occur mainly (not exclusively) because of two causes: not granting priority to pedestrians and pedestrians' illegal crossing. These accidents are closely linked to the urban life and this is shown by their distribution in time: 84.9% of accidents triggered by these two causes occurred during the week (Monday-Friday) and only 15.1% at the weekend. Hourly, they are related to the most active timeframe: 68.1% of them occur between 8.00 and 14.00. The road events generated by these two causes create their own spatial pattern that differs from inattention of drivers to unconsciousness of pedestrians (fig. 9-10).

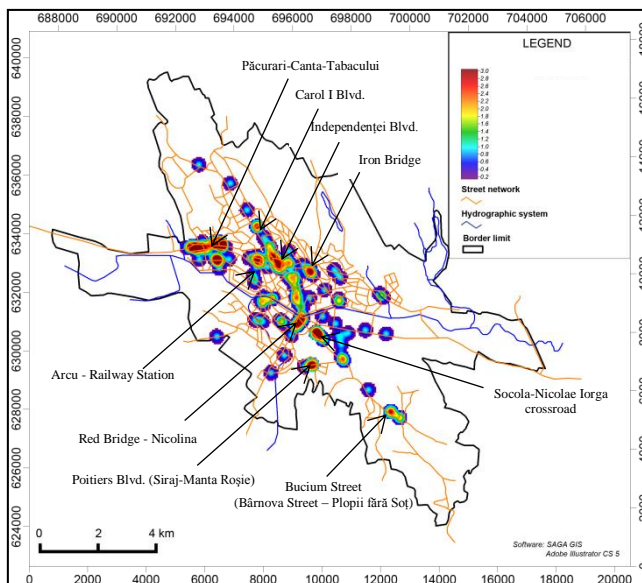


Fig. 9 Kernel density of road accidents caused by not granting priority to pedestrians (bandwidth – 264 m)

In the first case, vehicles are the key element and the map emphasizes the main roads that ensure the transit traffic through the city and create a linear pattern, from Nicolina and Socola to Red Bridge – Palace of Culture – Independenței, then to Carol I to the north and Păcurari to the west. Along these routes there are several hotspots that mark some intersections and pedestrian crossing: Red Bridge, Socola-Nicolae Iorga, Moara de

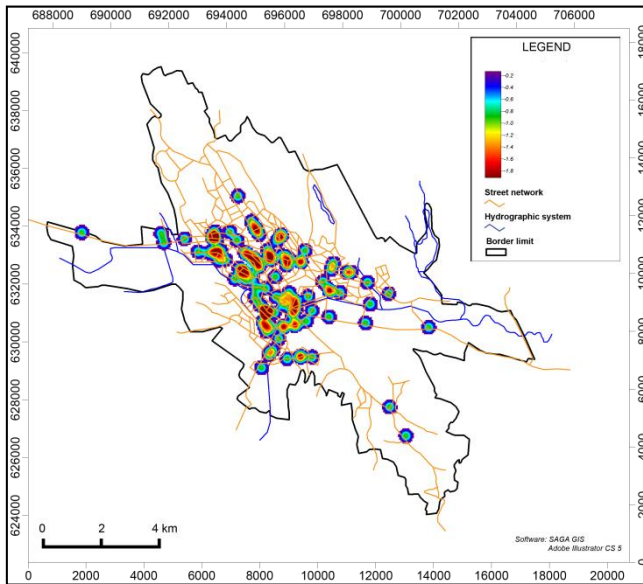
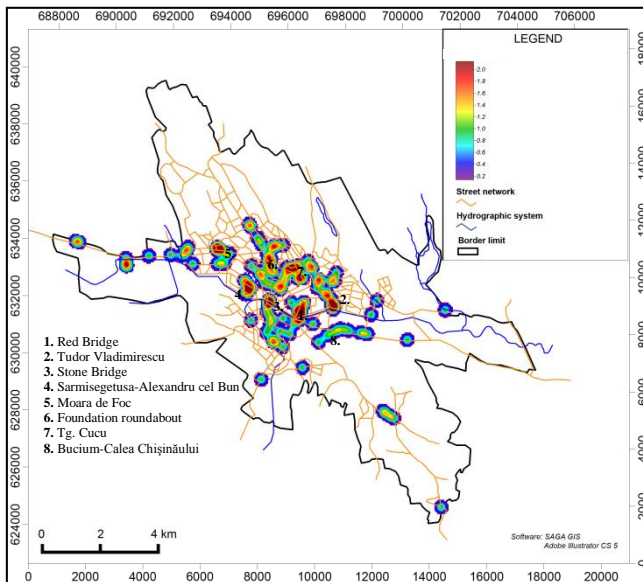


Fig. 10 Kernel density of road accidents caused by pedestrian illegal road crossing (bandwidth – 264 m)



Foc etc.

Other sectors with intense pedestrian and vehicle traffic are also well expressed: Siraj – Manta Roşie (Poitiers Blvd.), Iron Bridge etc (fig. 9). In the second case (fig. 10), the pedestrians are the key element and the spatial pattern does not have the same logic of linearity along the main roads. Nevertheless, like a statistical overlay, the highest values clearly show sectors with high frequency of accidents, but, unlike the first case, the map also shows the most agglomerate urban neighborhoods (Dacia, Alexandru, Canta, Nicolina etc). Most of the accidents caused by not granting priority to other vehicles (86.2%) occur during the week, as a consequence of urban activity, and determine 18.54% of all road injuries.

Fig. 11 Kernel density of road accidents caused by not granting priority to vehicles (bandwidth – 264 m)

III.2.3. Speeding and alcohol

Speeding is also one of the major causes of road accidents in Romania and in the most world countries. There are many studies that relate closely the speed to the road injury morbidity and mortality (Renski et al., 1999; Ossiander and Cummings, 2002; Soole et al., 2013). Nelson (2004) proposed a power model suggesting that number of injury and fatal accidents change according to a function power (fourth, third and second) of the relative change of traffic speed. The function powers are based on direct data from Sweden and have no theoretical foundation (Elvik et al., 2004), being still interesting to adapt in other conditions. Generally, the probability of physical injuries in road accidents is proportional to the square of speed, while the probability of fatal crashes is proportional to the fourth power of speed (Peden et al., 2004).

In Iași city, speed is the main cause of 15.07% of all accidents, but it is responsible for 26.7% of all road fatalities. As an important factor that influences the speeding drivers, we could blame the rush at the end of week, since 27.8% of accidents caused by speed occur on Friday, compared to the total weight of Friday accidents, which is much lower. Nevertheless, speeding is closely related to previous behaviors, attitudes, psychosocial characteristics and age of drivers (Scott-Parker et al., 2013).

It is suggestive the fact that the average age of drivers that caused accidents in Iași city is about 35 years, while the average age of drivers that caused accidents because of speeding is about 26 years. The speed record in our database is of 170 km/h and it was attained with a Lexus by a young of 22 years who caused an accident on Sărărie on 01.12.2011 at 0.20 a.m. Moreover, regarding the time, 48.14% of accidents caused by speed occurred during the night (between 23.00 and 6.00).

The highest frequency of accidents caused by speeding is recorded on the Carol I and Independenței boulevards, from Iron Bridge to Eternitatea and to the airport, but also to out of town, to Letcani, Poieni or Tomești (fig. 12), the last one being identified and signalized as “black point”. It should be mentioned that according to the Romanian police, a black point is a sector of no more than one kilometer where there have been recorded at least ten severe accidents in the last five years.

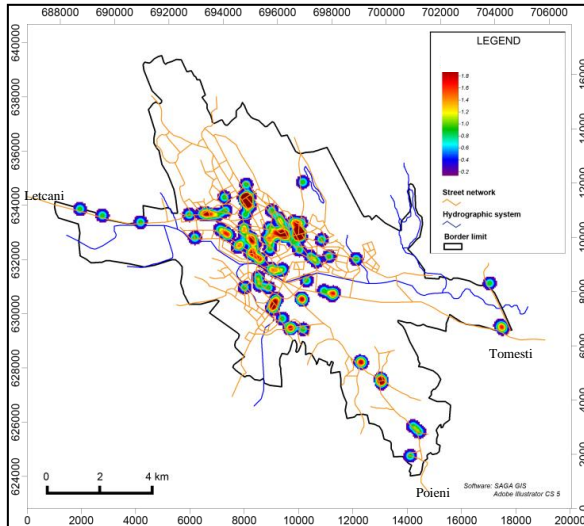


Fig. 12 Road accidents caused by speeding in Iași city

The gravity of some accidents results from the combination of speed with alcohol. Both speed and alcohol lead to an exponential increase of the relative risk of accidents (fig. 13). The alcohol itself was the main cause of 7.32% of car accidents that occurred within Iași city, but the alcohol was involved in 19.01% of all accidents, because the alcohol influences not only the perceptual ability and the responsiveness of drivers, but also their attitudes and behavior. Overall, there were potentiated by the alcohol 19.8% of accidents caused by speed, 16.91% of accidents caused by not granting priority to pedestrians, 15.44% of accidents caused by not granting priority to other vehicles etc.

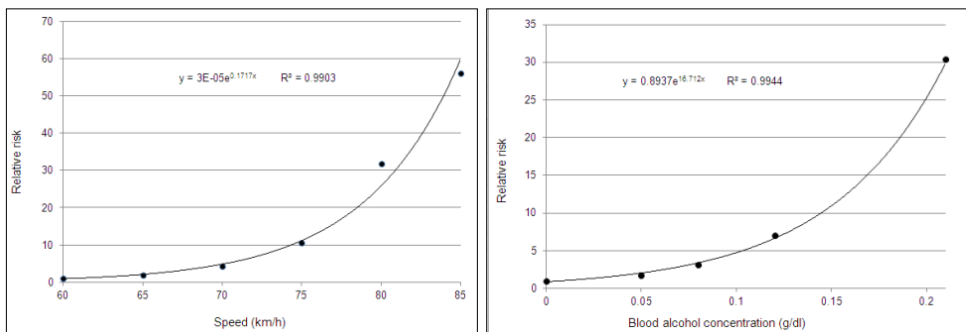


Fig. 13 Speed, alcohol and relative risk of road accidents (processed after McLean, J. and Kloeden, 2002)

It is interesting to observe that about 50% of the accidents caused directly by drunk driving occur between September and December during the year and from Friday to Sunday during the week. Also, based on partial statistics of our database, it is worrying that in 63.4% of accidents caused by alcohol, the pure alcohol content in air breathing of driver is very high (more than 0.8‰) and this means criminal liability, according to the Romanian Road Code.

V. CONCLUSIONS

This paper provides results in a field that, in Romania, unlike in other European countries, suffers from lack of analyses. The kernel density estimation used in this study enables a unitary vision on accidents occurring in a given area and emphasizes the hotspots (“black points”) that should be managed accordingly to improve the road safety and to minimize the traffic risks. Changing the kernel bandwidth allows performing interpretations at different levels, from the precisely local one (e.g. specific road intersection, specific pedestrian crossing or bus station etc.) to road level (road traffic on Independenței or Nicolae Iorga boulevard) and, then, to neighborhood or town level.

From the spatial analysis perspective, this means passing from punctual to linear and, then, to areal pattern. From the applicability point of view, for the road risk assessment, as the generalization level increases, we pass from direct measures to coherent policies that should flatten the hotspots all over the town by creating conditions for a safe and fluent traffic. Analyzing the passive factors, the catalyst and the triggering factors could enhance an efficient spending of public money, indicating to authorities when and what to look for in a specific place. From this point of view and limited by the database, although our study resumes making an overview on the main triggering factors of road accidents in Iași city, the results are encouraging and suggestive.

References

- Ancuța C., Muțulescu C.: Assessment of urban risk in the city of Timișoara (Romania), *International Journal of Energy and Environment*, 5-6, 496-507, 2012.
- Bailey, T. C., Gatrell, A. C.: *Interactive Spatial Data Analysis*. Essex: Longman, 1995.
- Benea, B., Dumitrascu, D.: Aspects regarding the injury severity in vehicle-pedestrian collisions, 2010.
- Călinoiu G., Minca D.G., Furtunescu L.F.: Analysis of Traffic Accidents in Romania, 2009, *Romanian Journal of Internal Medicine*, 50 (1), 93-101, 2012.
- Danciu, B., Popa, C., Micle, M. I., Preda, G.: Psychological risk factors for road safety, *Procedia-Social and Behavioral Sciences*, 33, 363-367, 2012.

- Davis G.A.: Relating severity of pedestrian injury to impact speed in vehicle pedestrian crashes, *Transportation Research Record*, 1773, 108-113, 2001.
- Duong, Tarn. ks: Kernel density estimation and kernel discriminant analysis for multivariate data in R, *Journal of Statistical Software*, 21.7, 1-16, 2007.
- Elvik, R., Peter C., Amundsen A: Speed and road accidents. An evaluation of the Power Model. TØI report 740 (2004), 2004.
- Fotheringham, A. S., Brunson, C., Charlton, M.: *Quantitative geography: perspectives on spatial data analysis*. SAGE Publications Limited. 2000.
- Gannoun, A., Saracco J., Yu K.: On semiparametric mode regression estimation. *Communications in Statistics - Theory and Methods*, 39.7, 1141-1157, 2010.
- Gheorghiu, Al., Havârneanu C.: Driving behaviour of a sample of young Romanian drivers. *Procedia-Social and Behavioral Sciences*, 33: 697-701, 2012.
- GIRP: http://www.politiaromana.ro/statistici_2004_2012.htm, accessed at December 11th 2012 and April 15th 2013.
- Grund, B., Hall P.: On the minimisation of L^p error in mode estimation, *The Annals of Statistics*, 23.6: 2264-2284, 1995.
- Holland, C. and Hill, R.: The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations, *Accident Analysis & Prevention*, 39 (2), 224-237, 2007.
- Iași County Police Inspectorate, Balance on 12 months of 2011 and 2012, 2012. Available on: http://is.politiaromana.ro/ipj_iasi/Media/Bilant_IPJ_Iasi_12_luni_2012.pdf
- Iliescu D., Sârbescu P.: The relationship of dangerous driving with traffic offenses: A study on an adapted measure of dangerous driving, *Accident Analysis and Prevention*, 51, 33-41, 2013.
- Ivan, K., Haidu, I.: The spatio-temporal distribution of road accidents in Cluj-Napoca, *Geographia Technica*, 2, 32-38, 2012.
- Jones, M. C., Marron S. J., and Sheather J. S.: A brief survey of bandwidth selection for density estimation, *Journal of the American Statistical Association*, 91.433 (1996), 401-407, 1996.
- Lotrean, L. M., Lotrean, S., Mocean, F., Laza, V., Del Valle, M. O.: Road Safety Related Behaviours of Romanian Young People. *Applied Medical Informatics*, 26 (1), 35-41, 2011.
- McLean, J., and Kloeden, C. N.: Alcohol, travelling speed and the risk of crash involvement. In *International Conference on Alcohol, Drugs and Traffic Safety* (16th, 2002, Montreal, Canada), 2002.
- Newton, J.: Road safety – Partnership program. Shared responsibility, Office of Road Safety, Perth, 2008.
- Nilsson, G.: Traffic safety dimensions and the Power Model to describe the effect of speed on safety, *Bulletin 221*, Lund Institute of Technology, Department of Technology and Society, Traffic Engineering, Lund, 2004.
- Osemwenkhae J.E., Ogebeide E.M.: Adaptive kernel density estimation: a review, *Nigerian Annals of Natural Sciences*, 10 (1), 88-96, 2010.

- Ossiander, E. M. and P. Cummings: Freeway speed limits and traffic fatalities in Washington State, *Accident Analysis and Prevention*, 34, 13-18, 2002.
- Peden M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A. A., Jarawan, E., Mathers, C. D. (eds.): *World report on road traffic injury prevention*, WHO, Geneva, 2004.
- Prato, C. G., Gitelman, V., Bekhor, S.: Mapping patterns of pedestrian fatal accidents in Israel. *Accident Analysis & Prevention*, 44 (1), 56-62, 2012.
- Renski, H., Khattak A. J., Council F. M.: Effect of speed limit increases on crash injury severity. *Transportation Research Record*, 1665, 100-108, 1999.
- Rosén E, Stigson H, Sander U.: Literature review of pedestrian fatality risk as a function of car impact speed, *Accident Analysis & Prevention*, 2011, 43, 25-33.
- Schabenberger, O., Gotway, C. A.: *Statistical Methods for Spatial Data Analysis*. Chapman & Hall/CRC, Boca Raton, Florida, 2005.
- Scott, D.W. and Terrell, G.: Biased and unbiased Cross –Validation in density estimation. *J. Amer. Statis. Assoc.*, 82: 1131-46, 1987.
- Scott-Parker, B., Hyde, M. K., Watson, B., & King, M. J.: Speeding by young novice drivers: What can personal characteristics and psychosocial theory add to our understanding?, *Accident Analysis & Prevention*, 50, 242-250, 2013.
- Silverman, B.: *Density Estimation for Statistics and Data Analysis*, 1st ed. Chapman and Hall, London, 1986.
- Soole, D. W., Watson, B. C., Judy, J.: *Effects of Average Speed Enforcement on Speed Compliance and Crashes: A Review of the Literature*. *Accident Analysis & Prevention*, 2013.
- Stângă I. C.: Spatio-temporal patterns of hazards and their use in risk assessment and mitigation. Case study of road accidents in Romania. In: EGU General Assembly Conference Abstracts, 10336, 2013.
- Stigson H., Krafft M., Tingvall C.: Use of fatal real-life crashes to analyze a safe road transport system model, including the road user, the vehicle, and the road, *Traffic injury Prevention*, 9, 463–471, 2008.
- Taylor, C. C.: Bootstrap choice of the smooth parameter in kernel density estimation. *Biometrika* 76: 705-712, 1989.
- TRC: Transport Research Centre. *Speed management report*, Paris, OECD Publishing, 2006.
- Wand M.P., Jones M.C.: Comparison of Smoothing Parameterizations in Bivariate Kernel Density Estimation, *Journal of the American Statistical Association*, 88, 520-528, 1993.
- WHO: *Global Plan for the decade of action for Road Safety 2011-2020*, 2009. Available from: http://www.who.int/roadsafety/decade_of_action/plan/plan_english.pdf
- WHO: *Saving millions of lives, Decade of Action for Road Safety 2011–2020*, Geneva, 2011.
- Xie, Z., Yan I. Kernel density estimation of traffic accidents in a network space, *Computers, Environment and Urban Systems* 32.5, 396-406, 2008.

Zegeer, C. V. and Bushell, M.: Pedestrian crash trends and potential countermeasures from around the world. *Accident Analysis & Prevention*, 44(1), 3-11, 2012.

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