



**Identification of  
traffic accident  
risk-prone areas**

K. Ivan et al.

This discussion paper is/has been under review for the journal Natural Hazards and Earth System Sciences (NHESS). Please refer to the corresponding final paper in NHESS if available.

# Identification of traffic accident risk-prone areas under low lighting conditions

**K. Ivan<sup>1</sup>, I. Haidu<sup>2</sup>, J. Benedek<sup>3</sup>, and S. M. Ciobanu<sup>1</sup>**

<sup>1</sup>Babeş-Bolyai University of Cluj-Napoca, Faculty of Geography, Clinicilor Street, 5–7, 400006 Cluj-Napoca, Romania

<sup>2</sup>Université de Lorraine, Laboratoire LOTERR – EA 7304, Ile du Saulcy, 57045 Metz, France

<sup>3</sup>University of Miskolc, Institute of World and Regional Economics, 3515 Miskolc, Hungary

Received: 22 January 2015 – Accepted: 1 February 2015 – Published: 17 February 2015

Correspondence to: K. Ivan (ivan\_kinga@yahoo.com)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



## Abstract

Besides other non-behavioural factors, the low lighting conditions significantly influence the frequency of the traffic accidents in the urban environment. This paper intends to identify the impact of low lighting conditions on the traffic accidents in the city of Cluj-Napoca. The dependence degree between lighting and the number of traffic accidents was analyzed by the Pearson's correlation and the relation between the spatial distribution of traffic accidents and the lighting conditions was determined by the frequency ratio model. The vulnerable areas within the city were identified based on the calculation of the injured persons rate for the 0.5 km<sup>2</sup> equally-sized areas uniformly distributed within the study area. The results have shown a strong linear dependence between the low lighting conditions and the number of traffic accidents in terms of three seasonal variations and a high probability of traffic accidents occurrence under the above-mentioned conditions, at the city entrances-exits, which represent also vulnerable areas within the study area. Knowing the linear dependence and the spatial relation between the low lighting and the number of traffic accidents, as well as the consequences induced by their occurrence enabled us to identify the high traffic accident risk areas in the city of Cluj-Napoca.

## 1 Introduction

The problems of road traffic safety are complex as there are some factors influencing their disturbance: the drivers' behaviour in traffic, the deterioration of infrastructure, the weather conditions, the lighting conditions, and the intensification of traffic. Due to the continuous increase of the traffic, the number of accidents increases significantly, while the road traffic safety becomes more difficult to control. The traffic accidents in the city of Cluj-Napoca have a generally high frequency along the main arterial roads. These arterial thoroughfares are congested mainly on the East–West direction, representing connection axes with the cities of Baia-Mare, Oradea, Zalau and Turda, with an average

# NHESSD

3, 1453–1472, 2015

## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



daily traffic of 84 390 vehicles. The intense road traffic in the city of Cluj-Napoca is due both to the transit traffic, to its area of economic influence, and to the large number of cars registered in the city and county. According to the data published by the National Institute of Statistics, 165 619 vehicles were registered in Cluj county in the 2012.

In order to mitigate the road accidents in the city, the triggering factors need to be identified first. Road traffic accidents are the result of both behavioural and non-behavioural factors.

The relation between accident frequency and the non-behavioural factors influencing their occurrence was investigated in many studies. Previous researches proved that non-behavioural factors have a significant influence on the occurrence of traffic accidents (Chang, 2005; Garber and Wu, 2001; Lee and Mannering, 1999; Petrova, 2011; Zou et al., 2012). These focused especially on the geometrical road characteristics, the traffic characteristics and the climatic conditions. The loss of life caused by bad weather conditions along the road network was analyzed by Petrucci and Pasqua (2012). Chang (2005) proved that the number of traffic lanes, the daily medium traffic, and the length of the road section have a significant influence on accident occurrence.

Within this paper we aimed to assess the traffic accident occurrence risk under low lighting conditions. The research is focused exclusively on the analysis of relation between the road traffic accidents and the lighting conditions, considered as non-behavioural factors of road traffic accidents occurrence. The road traffic accidents in urban areas may occur under various lighting conditions: dawn, daylight, cloudy sky, sunset or street lighting.

The dependence degree between the traffic accidents and the lighting conditions is analyzed in this paper by means of the statistical Pearson's correlation coefficient. The research conducted by Al-Harbi et al. (2012) by means of the Pearson's correlation coefficient investigated the relation between the meteorological conditions and the traffic accidents, and the results highlighted a strong correlation between temperature and accidents, during spring autumn and winter. The Pearson's correlation coefficient was also used to analyze the relation between the traffic accidents and the environ-

## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



**Identification of traffic accident risk-prone areas**

K. Ivan et al.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
⏪	⏩
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	



mental physical activity parameters in the study conducted by Stoupel et al. (2009). In the present paper, the research of the connection between the traffic accidents and the low lighting conditions enables us to determine the hazard, i.e. the triggering phenomenon. Hazards may be natural (earthquake, snow, cold wave, heavy rainfalls, low lighting etc.) or man-made (industrial, technological, chemical etc.), the latter being caused by human activities. The natural hazard, fatality risk caused by avalanches on road networks, was analyzed by Zischg et al. (2005). The current research focuses on the analysis of natural hazard – lighting, as a triggering phenomenon for the occurrence of traffic accidents.

In studying the relation between the spatial distribution of accidents and the various lighting conditions, the frequency ratio model and the Quadrat analysis were used. We decided to use the Quadrat analysis because this enables us to identify the 0.5 km<sup>2</sup> accident-prone areas in the city of Cluj-Napoca. The Quadrat analysis was used for the study of spatial relation between the traffic accidents by Mulrooney and Green (2012) and for the identification of areas with a high rate of crime incidents by Wing and Tynon (2006). The Frequency Ratio Model was used by Lee and Pradhan (2007) when analyzing the landslides susceptibility of slopes. We have adapted this method in our study to determine the road traffic accident-prone areas in the city concomitently with the decrease of lighting conditions. Susceptibility represents the occurrence potential of a traffic accident in a certain location, in our case the 0.5 km<sup>2</sup> areas.

Vulnerability represents the consequences resulted from the occurrence of traffic accidents, as these have a significant impact on the community. They may have a long-term occurrence (the basic vulnerability) or a short-term occurrence (the acute vulnerability), of an extreme nature (Benedek, 2002). Vulnerability may be: direct (material or moral losses) and indirect: economic (disruption of shops and factories supply), social (access to universities, schools) and security related (access of police, fire fighters, ambulance).

Direct vulnerability refers to the damages resulted immediately after the occurrence of the event and it is closely connected to the material or moral losses induced by

a traffic accident. The moral losses refer to the number of injured persons and deaths caused by the accident, while the material losses refer to the value of the damaged goods.

Indirect vulnerability refers to the distant consequences of the event and it is closely connected to the significance of the event where the accident occurred, the accessibility degree and its connectivity. In the present study we analysed only the direct vulnerability, i.e. the injury rate resulting from the traffic accidents.

In this paper, the risk is addressed as a result of summing up hazard, susceptibility and vulnerability. Some authors assess the risk as a product of probability and consequences (Stodola, 2008; Ferrier and Haque, 2003). After analyzing the three components: hazard, susceptibility and vulnerability, the present research determines the risk of traffic accidents occurrence under low lighting conditions.

The first part of the paper describes the data base used for risk assessment, while the second part presents the assessment of traffic accident occurrence risk under low lighting conditions, as sum of the three components.

## 2 Data description

In order to assess the risk of traffic accident occurrence under low lighting conditions, some data regarding the number of traffic accidents and the lighting conditions of their occurrence are necessary. A total number of 465 traffic accidents were recorded in Cluj-Napoca during the January 2010–June 2013 period. The data regarding the traffic accidents analyzed during this time interval are not homogenous, as the data set related to the accidents occurred in 2010 were obtained from the Cluj County Police Inspectorate, the Traffic Division, and those during the January 2011–June 2013 period were identified in the local press. The heterogeneousness of data is due to the difficulties met in achieving them for the entire study period, but this does not influence the spatial distribution of traffic accidents in the study area. The data contain information regarding the time, place, moment of the day and week, lighting conditions and number

## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



of victims caused by traffic accidents over the entire period of the study. The data on the road network contain information referring to the average speed of vehicles and the mean value of the accidents for each road segment in the city.

The data regarding the number of low visibility hours were calculated as the difference between the total number of hours and the sunshine duration (in hours) for each month. The sunshine duration data for the study period were achieved from the NCDC (National Climatic Data Centre) data base, corresponding to the Cluj-Napoca weather station.

### 3 Risk assessment

In the present paper, the risk is assessed as a sum of information resulted from hazard, susceptibility and vulnerability analysis. Risk as a sum of hazard, susceptibility and vulnerability was studied before by Panizza (1994) cited by Trizna (2000), Carrega (2003, 2008). Therefore, the risk assessment in this study implies the determination of the dependence degree and of the spatial relation between the traffic accidents and the low lighting conditions (hazard and susceptibility), as well as of the consequences induced by their occurrence (vulnerability).

#### 3.1 Hazard analysis

In this paper, hazard is identified by researching the relation between traffic accidents and the number of low visibility hours, based on the statistical correlation.

To set up a dependence relation, the two variables were distributed in a system of XOY axes, thus forming a correlation group. The correlation between the two variables, the low lighting and the traffic accidents is reflected by the simple linear regression model as follows:

$$Y = aX + b \tag{1}$$

where,  $X$  = the cause (lighting) and  $Y$  = the effect (road traffic accidents).

### Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



The statistical analysis identified three clusters, each with a certain tendency within the distribution, and these corresponded to three seasonal variations: end of summer–autumn, spring–beginning of summer and winter. The dependence between the two variables corresponding to the three seasonal variations was graphically represented by three regression lines, of the  $Y$  variable in relation to the  $X$  variable.

The intensity of the linear dependence between these two variables for each particular tendency was determined by means of the Pearson's correlation coefficient ( $r$ ). The Pearson's correlation coefficient ( $r$ ) of two variables  $x_i$  respectively  $y_i$  was calculated by the formula (Lee and Wong, 2001):

$$r = \frac{\frac{\sum_{i=1}^n x_i y_i}{n} - \bar{X} \cdot \bar{Y}}{S_x S_y} \quad (2)$$

where,  $\bar{X}$  and  $\bar{Y}$  represent the average of  $x$  and  $y$  and  $S_x$  and  $S_y$  represent the SD of  $x$  and  $y$ , calculated by the formulas (Lee and Wong., 2001):

$$S_x = \sqrt{\frac{\sum_{n=1}^n x^2}{n} - \bar{X}^2} \quad (3)$$

$$S_y = \sqrt{\frac{\sum_{n=1}^n y^2}{n} - \bar{Y}^2} \quad (4)$$

### 3.2 Susceptibility analysis

The identification of susceptible areas inferred the analysis of the relation between the spatial distribution of the accidents on a  $0.5 \text{ km}^2$  area and the various lighting conditions (dawn, daylight, cloudy sky, sunset or street lighting).

The spatial distribution of the accidents in equal and homogenous areas was performed by means of the Quadrat analysis. The Quadrat analysis was conducted in Arc View 3.2 by means of a script developed by Lee and Wong (2001). This analysis

**Identification of traffic accident risk-prone areas**

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



implied the cover of the study area with a grid of hexagons of equal size and the identification of the number of accidents placed in each hexagon. We opted for choosing the hexagon, due to a better visual display, compared to the traditional rectangular network; representation by hexagon offers a higher accuracy (Carr et al., 1992). The size of a chosen hexagon is  $0.5 \text{ km}^2$ , which allowed us to determine the areas susceptible to traffic accidents by relating the analysis to equal plots in the study area.

The susceptible areas determination procedure consisted in calculating the ratio between the traffic accidents in each  $0.5 \text{ km}^2$  area for each lighting condition and the percentage of the total number of accidents in the  $0.5 \text{ km}^2$  area. Thus, to determine the areas susceptible to the occurrence of traffic accidents, their frequency ratio was calculated for five different lighting conditions: dawn, daylight, cloudy sky, sunset or street lighting.

The susceptibility index of accident occurrence under low lighting conditions resulted by summing up the accidents frequency ratio for each condition and assignment of weights directly proportional with the decrease of the lighting conditions. Thus, the lighting conditions during night ( $N$ ) were assigned a weight of 35 %, during the day time ( $D$ ) a weight of 5 %, at sunset 25 %, at dawn 20 % and under cloudy sky conditions ( $C$ ) received a weight of 15 %. The formula used in calculating the susceptibility index is the following (adapted and modified from Lee and Pradhan, 2007):

$$S = \frac{35 \times N + 5 \times D + 25 \times S + 20 \times Dw + 15 \times C}{100} \quad (5)$$

where,  $S$  = the susceptibility index,  $N$  = the frequency ratio of accidents occurred at night,  $D$  = the frequency ratio of accidents occurred during the day,  $S$  = the frequency ratio of accidents occurred at sunset,  $Dw$  = The frequency ratio of accidents occurred at dawn and  $C$  = the frequency ratio of accidents occurred under cloudy sky conditions.

The high susceptibility rates locations represent the entrances/exits of the city: in the North part along the axis of Oasului Street, in the East part along the Muncii Boulevard, in the South part along the Calea Turzii Street, respectively in the West part the Calea Florești – 1 Decembrie 1918 Boulevard route (Fig. 1).



These axes of entrances/exits of the city according to the study conducted by Ivan and Haidu (2012) correspond to the main arterial roads with intense traffic and present a large number of victims.

### 3.3 Vulnerability analysis

This research comprises only the direct vulnerability, i.e. the direct consequences induced as a result of the traffic accidents, respectively the moral losses (victims of traffic accidents).

The vulnerability analysis was conducted by calculating the injury rate as a ratio between the number of victims and the total number of accidents occurred during the study period for each 0.5 km<sup>2</sup> area in the city.

The injury rate was calculated by the following formula (Pirotti et al., 2010):

$$IR = \left( \frac{I}{A} \right) \times 100 \quad (6)$$

where, IR = the injury rate, I = the number of injured persons and A = the number of accidents.

High vulnerability rates were recorded at the entrances/exits of the city, respectively those connecting to the North with Chinteni, to the East with Gherla and to the South with the town of Turda (Fig. 2). Lower vulnerability rates were recorded in the downtown area of the city.

## 4 Results and discussions

The areas with different degrees of accident occurrence risk under low lighting conditions were determined in this paper by summing up the information obtained as a result of hazard, susceptibility and vulnerability analysis.

## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



The research conducted on the statistical relation between the variables, the traffic accidents and the low lighting in order to identify the hazard revealed a linear dependence between them for each separate cluster identified. The correlation graph (Fig. 3) illustrates that the number of accidents ( $y_i$ ) increases concomitantly with the number of low lighting hours ( $x_i$ ). There is a direct linear connection between the two variables ( $X$  and  $Y$ ).

The intensity of linear dependence between the two variables corresponding to the three seasonal variations is given by the correlation coefficients which are positive for each of the variations. The Pearson's correlation coefficient with the highest value is 0.97 and corresponds to the months of March, April, May, and June, that of 0.91 for the months of December, January, February, and the 0.85 coefficient for the months of July, August, September, October, November.

This dependence between the two variables is represented on the correlation graph by three regression lines, and of all these, the best approximation is ensured by the regression line with a determination coefficient of 0.94. The 0.72, 0.94 and 0.83 determination coefficients are close to 1 and indicate the fact that low lighting ( $X$ ) explains the variation of the  $Y$  variable (traffic accidents) in the ratio of 72, 94 and 83 %, which shows that the model is valid in explaining the variation of the road traffic accidents.

The identification of the areas susceptible to traffic accidents produced under low lighting conditions emphasizes their high rate at the city outskirts, respectively in the entrance/exit points of the city where the speed of vehicles is high.

The research of the dependence degree between the average of traffic accidents ( $Y$ ) and the average vehicle speed ( $X$ ) at the level of each road segment for the study period highlighted a direct statistical relation. This illustrates the fact that an increase of  $y_i$  corresponds to an increase of  $x_i$ .

The statistical analysis has identified two clusters within the distribution, one corresponding to the average speeds up to  $44 \text{ km h}^{-1}$ , and the other one including the speeds of  $50 \text{ km h}^{-1}$ , respectively  $60 \text{ km h}^{-1}$  and probably higher. The speeds higher than  $60 \text{ km h}^{-1}$  were not analyzed in this study. The intensity of the linear dependence

**Identification of traffic accident risk-prone areas**

K. Ivan et al.

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

between the two variables was determined by means of the statistical correlation. The values of Pearson's correlation coefficient obtained within this analysis are high, 0.96 in case of the dependence between the traffic accidents and the speed of vehicles up to  $44 \text{ km h}^{-1}$ . The Pearson's correlation coefficient between the traffic accidents and the vehicle speeds up to  $60 \text{ km h}^{-1}$  was a little lower than 0.78. The dependence between the variables, the traffic accidents and the speeds up to  $60 \text{ km h}^{-1}$  was graphically represented by means of an exponential curve, while that between the traffic accidents and the speeds up to  $44 \text{ km h}^{-1}$ , by means of a linear curve (Fig. 4). The 0.84 and 0.93 determination coefficients indicate the fact that speed of vehicles ( $X$ ) explains the variation of the  $Y$  variable (traffic accidents) in the ratio of 84 and 92 %.

These results explain the fact that in the Cluj-Napoca city, speed is another factor favouring the occurrence of traffic accidents, beside low lighting and the intense road traffic.

After identifying the vulnerable areas, the results have shown low rates in the central areas of the city, where accident frequency recorded high values during the period of study. This highlights the fact that the gravity of road accidents was low in this area although the frequency of the accidents was high. The high accident frequency in these areas is due to the intense road traffic, as it comprises the main traffic roads in the city, which host the transit traffic. This is due to the architecture of the city, which extends on the East–West axis, as well as to the traffic infrastructure which could not adapt to the increase of the road traffic density in the city.

The results of the risk assessment emphasized a high degree of traffic accidents occurrence under low lighting conditions in the areas with a high vulnerability rate and this explains the fact that the risk degree depends on the population's vulnerability degree.

The areas with a high traffic accident occurrence rate under low lighting conditions are illustrated on the map in dark grey and are located approximately at the entrances/exits of the city. Hence, we find six such areas, three of them located in the South of the city, one in the North and two in the East (Fig. 5).

**Identification of traffic accident risk-prone areas**

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



The most Southern high risk area includes the Southern end of the Calea Turzii Street, representing the entrance/exit of the Cluj-Napoca city towards the town of Turda. Here the high risk is explained by the fact that visibility is disturbed by the presence of two dangerous curves in conjunction with the high vehicle speed on this arterial road (50 km h<sup>-1</sup>), with the intense vehicle flow (the average daily traffic is 476 vehicles). The second Southern area with a high risk of road traffic accidents occurrence under low lighting conditions includes the streets Buna Ziua and Borhanci, where the access of heavy vehicles is allowed exclusively with authorization. In this area, the number of heavy vehicles per day is on average 179.

In the North part of the city, the high risk areas include the following arterial streets: Oasului Street, Fabricii Street and Muncii Boulevard. The high risk in this area is due to the intense road traffic, to the presence of the heavy vehicles, as well as to the high speed along certain sectors. The average daily traffic on the Oasului Street is 977 vehicles, the average speed of vehicles is 60 km h<sup>-1</sup> and the number of heavy vehicles per day is more than 42. The average daily traffic on the Fabricii Street is 163 vehicles, the average vehicle speed is 50 km h<sup>-1</sup> and the number of heavy vehicles per day is 161.

In the Eastern part of the Cluj-Napoca City there are two high risk areas in terms of traffic accidents under low lighting conditions, one located in the airport area and one at the end of the Muncii Boulevard. The high risk rate in these areas is due to the intense traffic (the average daily traffic is 103 vehicles) and to the high vehicle speed near the airport (50 km h<sup>-1</sup> average speed).

**5 Conclusions**

The assessment of traffic accident occurrence risk under low lighting conditions was determined as a sum of hazard, susceptibility and vulnerability. The areas with the highest risk rates identified at the city level include the most important arterial roads, consisting generally in entrances/exits of the city such as Calea Turzii, Oasului Street,

## Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Muncii Boulevard and the airport area. These arterial roads represent important transit axes, with high speed of vehicles and intense traffic. The high vehicle speed on the Calea Turzii Street is  $50 \text{ km h}^{-1}$  and the average daily traffic is 476 vehicles, on the the Oasului Street the average speed of vehicles is  $60 \text{ km h}^{-1}$  and the average daily traffic is 977 vehicles, on the Muncii Boulevard and the airport area, the average daily traffic is 103 vehicles and the average speed of vehicles is  $50 \text{ km h}^{-1}$ .

The research on the dependence degree between the road traffic accidents and the non-behavioural factors (speed and low lighting) emphasized the fact that lighting and speed are favouring factors in accident occurrence. The knowledge of these factors and the identification of risk areas may help the local authorities in finding and implementing measures for the prevention and mitigation of the number of road traffic accidents. These measures should include the expansion and development of street lighting, lowering the speed limits on certain traffic routes, location of warning signboards etc. If implemented, all these measures would lead to a higher safety of road traffic.

*Acknowledgements.* This paper is a result of a doctoral research made possible by the financial support of the Sectoral Operational Programme for Human Resources Development 2007–2013, co-financed by the European Social Fund, under the project POSDRU/159/1.5/S/132400 – “Young successful researchers – professional development in an international and interdisciplinary environment”.

## References

- Al-Harbi, M., Yassin, M. F., and Bin Shams, M.: Stochastic modeling of the impact of meteorological conditions on road traffic accidents, *Stoch. Environ. Res. Risk A.*, 26, 739–750, 2012.
- 5 Benedek, J.: *Human Risks, Riscuri și Catastrofe*, Cluj University Press, Cluj-Napoca, 1, 43–54, 2002.
- Carr, D. B., Olsen, A. R., and White, D.: Hexagon mosaic maps for display of univariate and bivariate geographical data, *Cartogr. Geogr. Inform.*, 19, 228–236, 1992.
- Carrega, P.: *The Natural Risks Connected to Rainfall and Drought: Drawing Maps of Extreme Rainfalls and Risks of Forest Fires within a Mediterranean Region: Toscana (Italy)*, *Riscuri și Catastrofe*, Cluj University Press, Cluj-Napoca, 2, 271–286, 2003.
- 10 Carrega, P.: Forest fire risk in region mediterranean: understanding and development, in: *Actes du XXIIe colloque de l'Association Internationale de Climatologie*, HAL, Montpellier, 11–23, 2008.
- 15 Chang, L.-Y.: Analysis of freeway accident frequencies: negative binomial regression versus artificial neural network, *Safety Sci.*, 43, 541–557, 2005.
- Ferrier, N. and Haque, E. C.: Hazards risk assessment methodology for emergency managers: a standardized framework for application, *Nat. Hazards*, 28, 271–290, 2003.
- Garber, N. J. and Wu, L.: Stochastic models relating crash probabilities with geometric and corresponding traffic characteristics data, *Publication UVACTS-5-15-74*, Center for Transportation Studies, University of Virginia, Charlottesville, VA, 2001.
- 20 Ivan, K. and Haidu, I.: The spatio-temporal distribution of road accidents in Cluj-Napoca, *Geographia Technica*, 16, 32–38, 2012.
- Lee, J. and Mannering, F.: *Analysis of Roadside Accident Frequency and Severity and Roadside Safety Management*, Washington State Department of Transportation, University of Washington, Seattle, USA, 1999.
- 25 Lee, J. and Wong, D. W. S.: *Statistical Analysis with ArcView GIS*, John Wiley and Sons, New York, 192 pp., 2001.
- Lee, S. and Pradhan, B.: Landslide hazard mapping at Selangor, Malaysia using frequency ratio and logistic models, *Landslides*, 4, 33–41, 2007.
- 30

## NHESSD

3, 1453–1472, 2015

### Identification of traffic accident risk-prone areas

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



**Identification of traffic accident risk-prone areas**

K. Ivan et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Mulrooney, T. and Green, E.: Exploring Patterns And Factors Related To Deer-Vehicle Collisions In Central North Carolina, Southeastern Division of the Association of American Geographers, Annual Meeting, 18–20 November, Asheville, North Carolina, 2012.

National Institute of Statistics, Romania, available at: [www.insse.ro](http://www.insse.ro), last access: August 2012.

5 Petrova, E. G.: Natural factors of technological accidents: the case of Russia, *Nat. Hazards Earth Syst. Sci.*, 11, 2227–2234, doi:10.5194/nhess-11-2227-2011, 2011.

Petrucci, O. and Pasqua, A. A.: Damaging events along roads during bad weather periods: a case study in Calabria (Italy), *Nat. Hazards Earth Syst. Sci.*, 12, 365–378, doi:10.5194/nhess-12-365-2012, 2012.

10 Pirotti, F., Guarnieri, A., and Vettore, A.: Road safety analysis using web-based collaborative GIS, vol. 34 pp, *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Como, Italy, 2010.

Stodola, J.: Possibilities of traffic accidents and risk crash evaluation, *R&RATA # 2*, 1, 134–138, 2008.

15 Stoupel, E., Babayev, E. S., Shustarev, P. N., Abramson, E., Israelevich, P., and Sulkes, J.: Traffic accidents and environmental physical activity, *Int. J. Biometeorol.*, 53, 523–534, 2009.

Trizna, M.: Flood threat in an area – topical natural hazard, *Acta Universitatis Palackianae Olomucensis, Geographica*, 36, 89–96, 2000.

Wing, M. G. and Tynon, J.: Crime mapping and spatial analysis in national forests, *J. Forest.*, 104, 293–298, 2006.

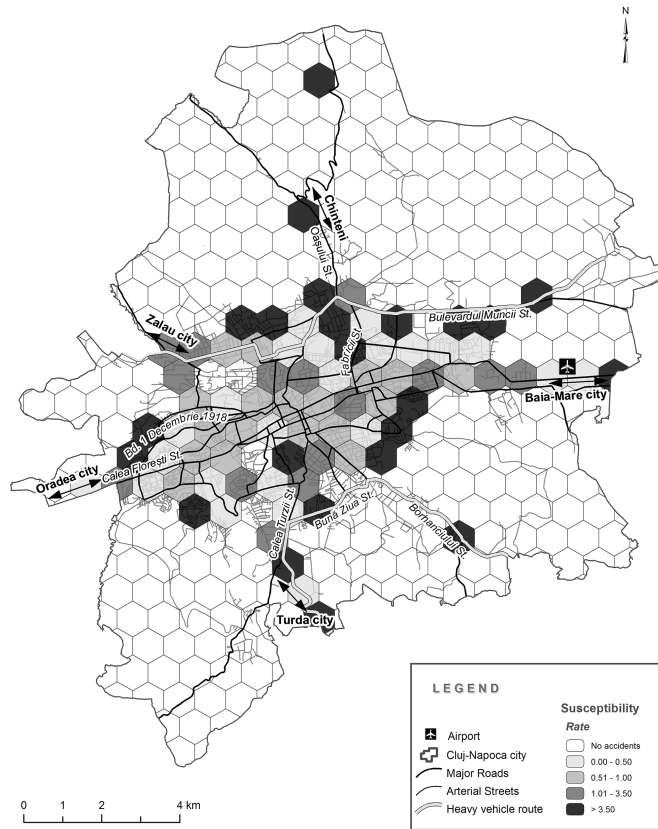
20 Zischg, A., Fuchs, S., Keiler, M., and Stötter, J.: Temporal variability of damage potential on roads as a conceptual contribution towards a short-term avalanche risk simulation, *Nat. Hazards Earth Syst. Sci.*, 5, 235–242, doi:10.5194/nhess-5-235-2005, 2005.

Zou, Y., Lord, D., Zhang, Y., and Peng, Y.: Comparison of Sichel and Negative Binomial Models in Estimating Empirical Bayes Estimate, *Transportation Research Record*, Paper presented at the 93rd Annual Meeting of the TRB, Washington, D.C., 2012.

25

## Identification of traffic accident risk-prone areas

K. Ivan et al.



**Figure 1.** The map of areas susceptible to traffic accidents under low lighting conditions in Cluj-Napoca (2010–2013).

Title Page

Abstract Introduction

Conclusions References

Tables Figures

◀ ▶

◀ ▶

Back Close

Full Screen / Esc

Printer-friendly Version

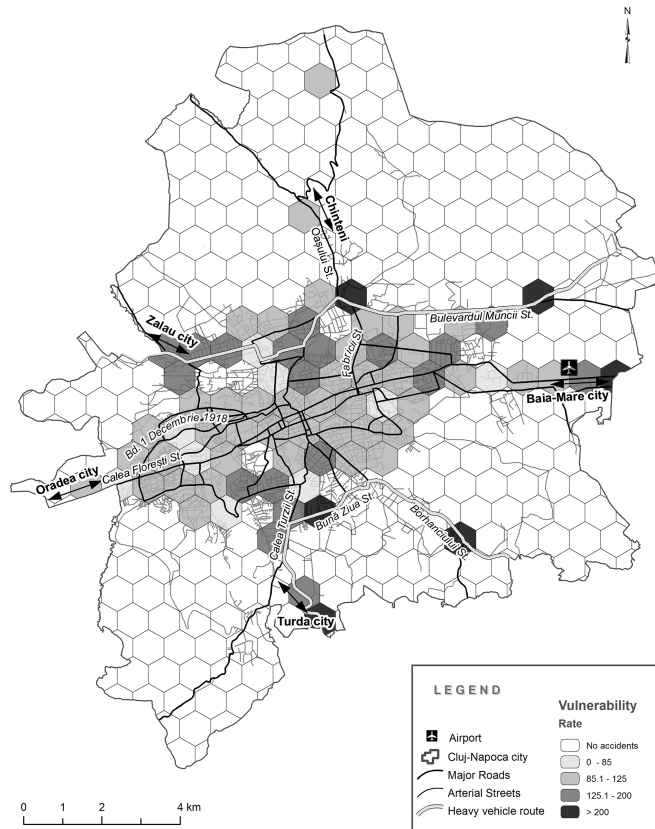
Interactive Discussion





## Identification of traffic accident risk-prone areas

K. Ivan et al.



**Figure 2.** The map of vulnerable areas in the city of Cluj-Napoca (2010–2013).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

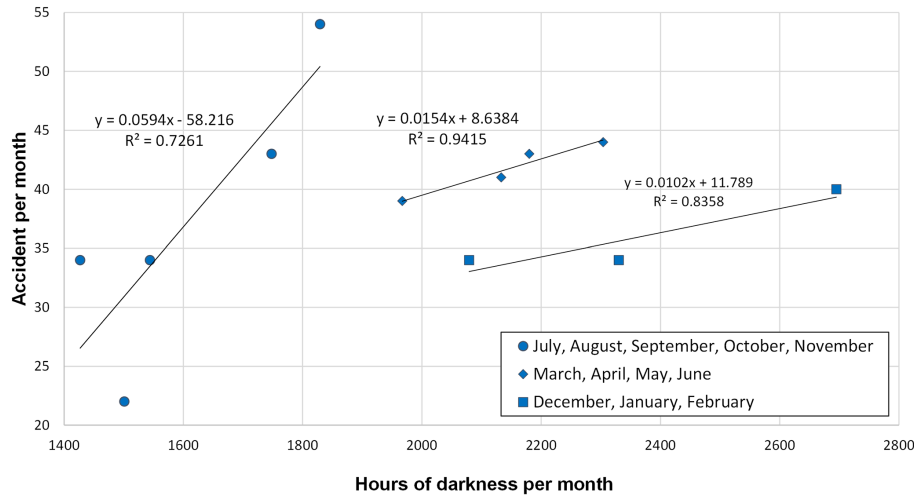
Printer-friendly Version

Interactive Discussion



## Identification of traffic accident risk-prone areas

K. Ivan et al.



**Figure 3.** The regression lines corresponding to the three seasonal variations (2010–2013).

Title Page

Abstract Introduction

Conclusions References

Tables Figures

⏪ ⏩

◀ ▶

Back Close

Full Screen / Esc

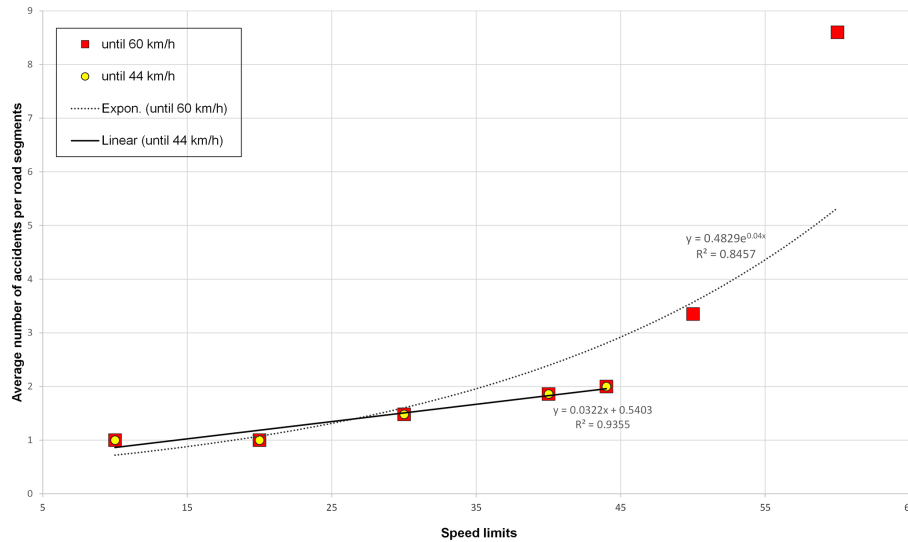
Printer-friendly Version

Interactive Discussion



## Identification of traffic accident risk-prone areas

K. Ivan et al.



**Figure 4.** The correlation graph between the speed and traffic accidents variables (2010–2013).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

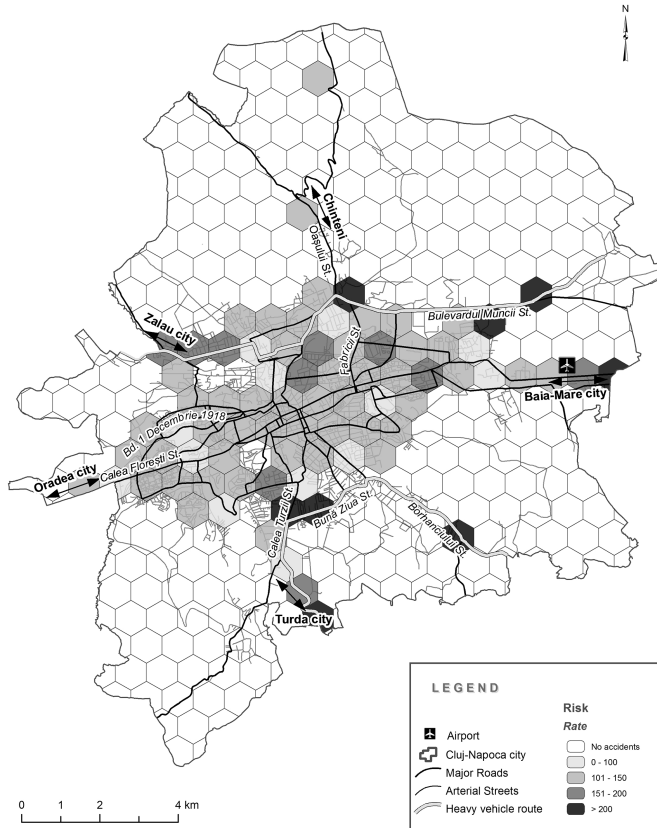
Printer-friendly Version

Interactive Discussion



## Identification of traffic accident risk-prone areas

K. Ivan et al.



**Figure 5.** The map of traffic accident occurrence risk areas under low lighting conditions, Cluj-Napoca (2010–2013).

Title Page

Abstract Introduction

Conclusions References

Tables Figures

◀ ▶

◀ ▶

Back Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

