Bulletin of Geography. Socio–economic Series / No. 35 (2017): 81–92

ISSN 1732–4254 quarterly

BULLETIN OF GEOGRAPHY. SOCIO–ECONOMIC SERIES
journal homepages:
http://www.bulletinofgeography.umk.pl/
http://wydawnictwoumk.pl/czasopisma/index.php/BGSS/index
http://www.degruyter.com/view/j/bog

Geographical modelling based on spatial differentiation of fire brigade actions: A case study of Brno, Czech Republic

Jan Popelínský[1, CDFM], **Jan Vachuda**[2, CDFMR], **Ondřej Veselý**[1, CD]

Masaryk University, Faculty of Science, Department of Geography, Kotlářská 267/2, Brno, Czech Republic; [1]e-mail: 184443@mail.muni.cz (*corresponding author*); [2]e-mail: pelco@email.cz; [3]*Mendel University*, Faculty of Business and Economics, Department of Informatics, Zemědělská 1, Brno, Czech Republic; e-mail: xorwen@gmail.com

How to cite:
Popelínský, J., Vachuda, J. and Veselý, O., 2017: Geographical modelling based on spatial differentiation of fire brigade actions: A case study of Brno, Czech Republic. In: Rogatka, K. and Szymańska, D. editors, *Bulletin of Geography. Socio-economic Series,* No. 35, Toruń: Nicolaus Copernicus University, pp. 81–92. DOI: http://dx.doi.org/10.1515/bog-2017-0006

Abstract. The paper analyzes crisis situations solved by The Fire Rescue Service of the South Moravian Region (FRS) in the city of Brno during 24 weeks between 7th April 2013 and 20th September 2013. The article deals briefly with all FRS actions and then focuses on fires. The open-access database of FRS is used for analysis. It is accessed from a database of the innovative web application StreetAlert, which allows users to learn about current fire brigade actions in the specified distance from the mobile phone. The data are processed in PostgreSQL and then spatial analysis is performed using the most detailed administrative division of the city – basic settlement units. As this division of urban space is used also in the most recent Czech census (2011), it is possible to use sociodemographic statistical data for comparison. The article identifies spatial regularities in the distribution of fires, describes the structure of the fires in terms of the type of event (fires of waste, fires of grass and forest, fires of buildings), discovers their possible dependence on the specific characteristics of urban space, finds potentially dangerous places (kernel density analysis), draws valid conclusions applicable to similar settlements, and shows the possible use of the data for local government. The main benefit of the research lies in revealing the spatial distribution of the examined phenomena.

Article details:
Received: 28 November 2015
Revised: 22 August 2016
Accepted: 23 October 2016

Key words:
spatial analysis,
fires,
urban space,
database,
GIS

Contents:

1. Introduction

Spatial modelling helps to understand dependencies between urban socioeconomic variables and other important phenomena such as fire brigade actions. The database of The Fire Rescue Service (FRS) actions in Brno, Czech Republic provides the background for the research on the activities of the FRS and spatial distribution of these events. The goals of the paper are:

(1) modelling of FRS actions,
(2) understanding the spatial distribution of these events,
(3) explaining the dependencies on other phenomena within urban space,
(4) understanding the causes of these situations,
(5) improving the preparedness of The Fire Rescue Service and the decision-making process of governmental authorities.

Giddens (1999) says: 'We live in a world where hazards created by ourselves are as, or more, threatening than those that come from the outside'. Fire is understood to be one of natural hazards, but the types of fires mentioned in this study certainly can be taken as hazards created by ourselves. Giddens also distinguishes between the terms 'hazard' and 'risk': 'Risk refers to hazards that are actively assessed in relation to future possibilities'. Again risks are sorted by their causes. External risk is coming from the outside, for example from nature. Savanna fires fall into this category, whereas fires of waste or fires of buildings are examples of manufactured risk, risk which is created by the very impact of our developing knowledge upon the world'.

'Spatiotemporal analysis of fire incidents could provide useful information for planning of fire prevention and response activities in terms of risk identification, resource targeting and routing of fire personnel and equipment, allocation of preventative measures, and policy evaluation' (Asgary, 2010). This kind of information can be very useful for reducing risk, addressing social and institutional capacities, reducing the vulnerability of cities, maximum utilizing of the resilience of the public and for using the best practices for handling urban fire events (Pelling, 2003).

Previous ecological research found an association between fires and housing conditions and population density (Jennings, 2013). Expected associations between poverty, substandard and overcrowded housing and increased fire incidence were generally approved (Fahy, 1989 in Jennings, 2013).

The socio-economic factors which increase fire risk according to the study based on New-Zealand 1993-1998 data of fatal fire incidents were: under-education (% of persons aged over 25 with less than 8 years schooling), housing crowdedness (% of households with more than one person per room), and poverty (% of persons below the poverty level). On the other hand, the factors which generally decrease fire risk were home ownership, adequate income, parental presence, and good education (Duncanson et al, 2002). Other studies also analyzed population density, demographic characteristics, buildings types and the level of education which were found to correlate with such variation (Krisp et al, 2005; Corcoran et al, 2007).

Detecting hot spots in kernel density estimation is a very popular spatial technique used in more recent studies (e.g. Asgary, 2010; Corcoran et al, 2007). Chetri et al. used 22 socioeconomic variables in the construction of the index of social deprivation and observed that areas with lower social status resulted in higher incidence of fires (Chetri, 2010).

Corcoran et al. (2011) created a framework for the conceptualization (Fig. 1) of fire incidents on extensive research in New South Wales which included socioeconomic characteristics, calendar events and temperature, rainfall and humidity. This framework showed many variables which can be very dif-

ficult to obtain. The Czech Integrated Fire Rescue Service (FRS) uses another framework for evaluating the conditions of fires and improving fire rescue management. (Janata et all, 2009; Skalská et al., 2010). The framework by Corcoran et al. (2011) can be used also in the conditions of central Europe.

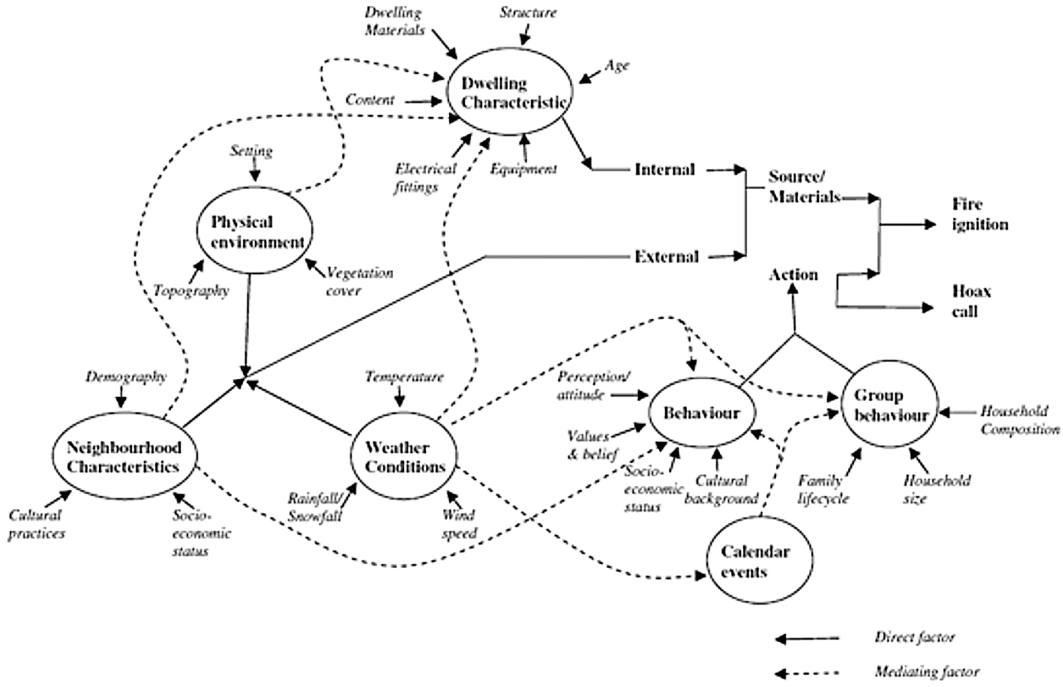

Fig. 1. Conceptualization of fire incidents

Source: Corcoran et al., 2011

In studies of fires and risks events it is also important to perform a holistic kind of research, which uses sophisticated quantitative analytical techniques in collaboration with qualitative research, which is based on behavioral or humanistic aspects of geography and on rethinking objective space in the city. This type of research is covered by population-based studies. For example, Wallace and Wallace (2001) investigate the impact of specific individuals within the community which can cause higher fire risk.

The application of research is also an important part of the discussion about fire incidents. Collaboration between academics and fire services is essential for understanding fire incidence and loss better, improving fire safety and reducing the toll of fire, especially for those communities at greatest risk of fire (Jennings, 2013).

Krömer et al. (2010) introduced special cumulative risk maps, which integrate maps of fire events (or other possibilities such as floods) and maps of insecurity or maps of vulnerability, with areas which have different levels of vulnerability (critical points of infrastructure, population areas, etc.) and also a map of preparation services with locations of basic points of fire rescue services, hospitals, police and early-warning systems (Krömer et al., 2010).

Reducing vulnerability has a fundamental role in risk management strategies. Vulnerability can be considered in terms of five components (1) initial well-being, strength and resilience, (2) self-protection, (3) social protection, (4) livelihood resilience, and (4) social capital. (Wisner et al, 2005).
All components are strongly cross-related and determined by political, economic or social processes.

The perception of actors and their interpretation of phenomena also play a highly important role in risk management. Sjöberg (1999) shows the differences of perceptions of risk management by the public and by experts. In the interpretation of risk management the typology of experts is important,

because experts often play the roles of "Promotors" or "Protectors". Experts in the role of "protectors" warn people about a risk that they do not know about or neglect to protect themselves against. Promoters, on the other hand, regret that people are too much concerned about risks and ask how they can be convinced that those risks are not so large. (Sjöberg, 1999). In the interpretation of risk assessment an expert has to realize his or her role in the preservation of scientific interpretation.

Modelling of fires as a multidisciplinary research covers social and physical geography, geoinformatics, statistics or even psychology. In our study we will focus on the geographical and statistical aspect of the problem. Whilst GIS methods will allow us to view and analyze the quantitative nature of fire events, the contribution of advanced statistical technics, psychology specialists and experts, who know the local conditions is still needed for a deeper comprehension or interpretation of the phenomena.

2. Research material and methods

2.1. Research area

The city of Brno, the second largest city in the Czech Republic with population of 385 913 (Census, 2011), is located in the South Moravian region (Fig. 2) on the confluence of the Svratka and Svitava rivers. Brno has a historical centre with mostly Art Nouveau buildings built after the city renewal at the beginning of the 20th century. The centre is surrounded by a ring "strasse" – a copy of the original Viennese urban element. The structure of the city then changes from villas or family houses near the centre to housing estates on the periphery.

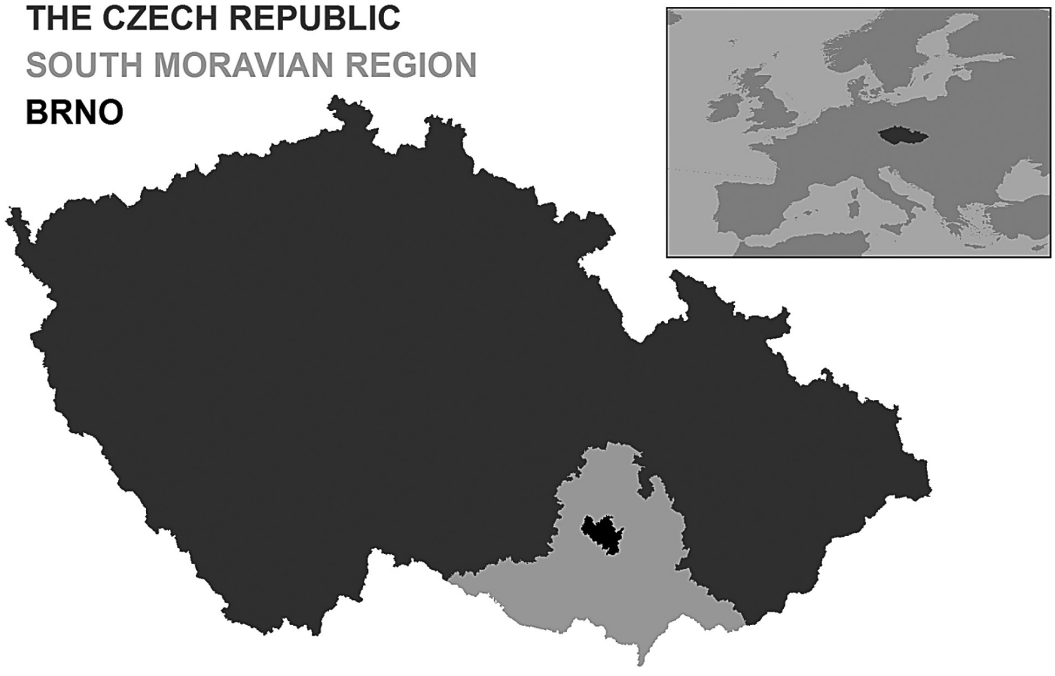

Fig. 2. Location of the research area based on database ArcČR 500

Source: Developed by the authors based on data from ARCDATA Praha, 2013

2.2. Data and methods

Input data were primarily provided by The Fire Rescue Service of the South Moravian region for an/ /the application called „Streetalert", which was developed by one of the authors of this paper. The application can report on a mobile phone the real time FRS actions at a chosen distance from the

mobile phone (Řihák, Veselý, 2012). A part of this large amount of data was then exported into text format and used for this study. The authors received access to the period of less than 24 weeks (7th April 2013 and 20th September 2013). The data contain events from the whole region of South Moravia (3500 events) – 977 events in the research area of Brno (Fig. 3). Among the most important categories there were fires (31 %) and car accidents (12 %), but the structure of FRS actions is significantly more heterogeneous. It comprises 10 more categories, e.g. tree removal, liquidation of dangerous insect, water issues or blocked up rooms.

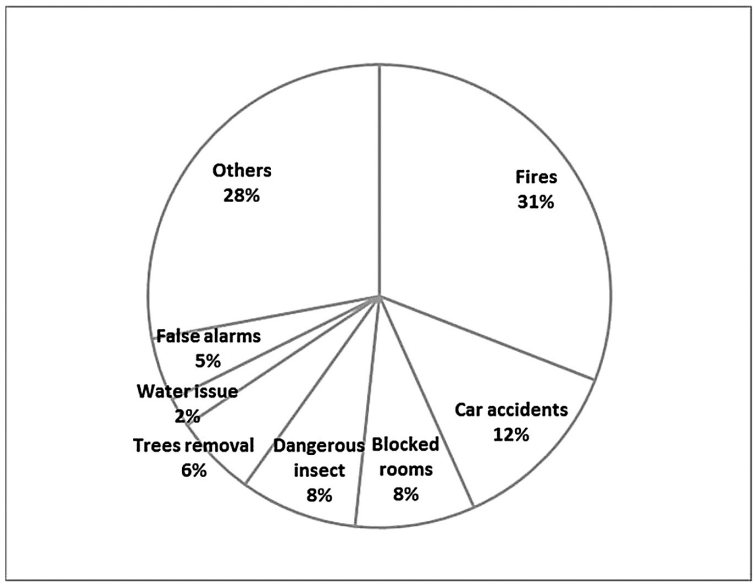

Fig. 3. The Fire Rescue Service events classified into subcategories in the city of Brno

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013

The text database was edited with the tools of PostgreSQL. Table output from PostgreSQL was transformed into spatial data in ArcMap 10.1. The point shapefile was statistically analyzed and visualized in the ArcGIS environment. The performed analyses included Kernel Density analysis, which creates a raster with the values of count of events in a given distance (750 m). The raster helps to identify key problem localities with a higher density of fires.

The analysis of all FRS actions showed a natural accumulation tied to densely inhabited areas in the centre of Brno and northwards from the centre. It is also possible to identify main roads as locations with a higher accumulation of FRS actions (Fig. 4). However, it is not possible to draw a valid conclusion due to the very heterogeneous nature of FRS actions. It was decided to focus only on fires, because they are the most frequent class of events. This restriction also allows us to find the driving forces of the phenomenon and to identify how deeply they depend on certain urban processes and patterns.

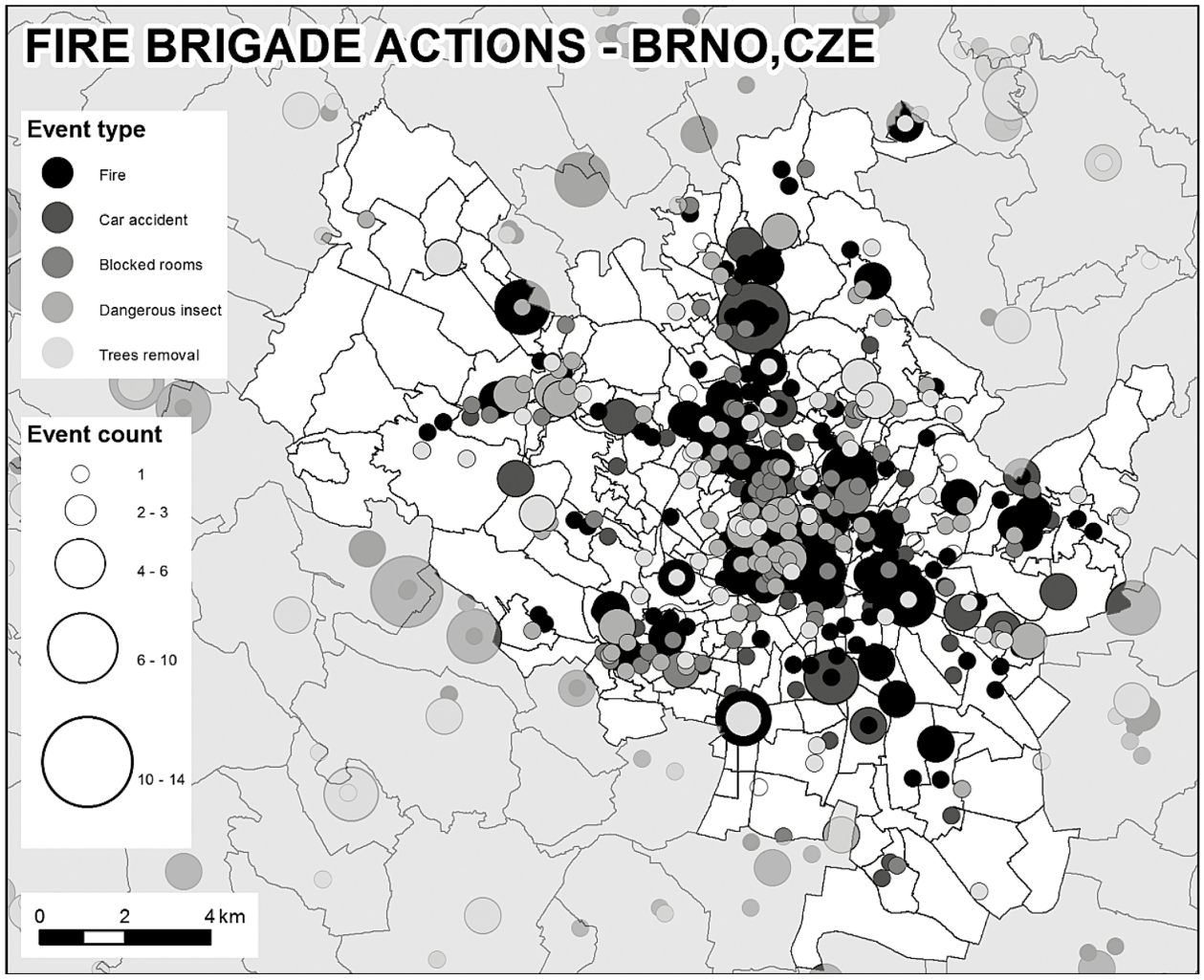

Fig. 4. Type and quantity of fire brigade action

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013 and ARCDATA Praha, 2013

3. Research Results

3.1. Overview

At first we discovered a possible dependence of fires on the specific characteristics of urban space. There is a considerable concentration of fires in the centre and in other places with a higher density of population. This relation is expectable and is proven by the computed kernel density map (Fig. 5) and the choropleth map (Fig. 6). Fig. 5 shows two "beams" with a higher occurrence of fires – in the north-western and south-eastern direction. The north-western beam is characterized by a very high population density; the south-eastern beam has an average population density but a lower state of buildings. It is also possible to identify "safe" areas (areas without fires or with a low concentration of fires) tied to the location of family houses and higher social status of their inhabitants.

The comparison of the fire count in a specified administrative unit with the population density in the unit was described above. Another socioeconomic characteristic of urban space which could have some relation with fire count is unemployment rate as a an indicator/ a sign of the social status of inhabitants. There can be seen visual similarity in the distribution of those two phenomena in Fig. 6. Performed statistical analysis (correlation) showed the same results, but the results were not statistically significant because of lack of data quantity.

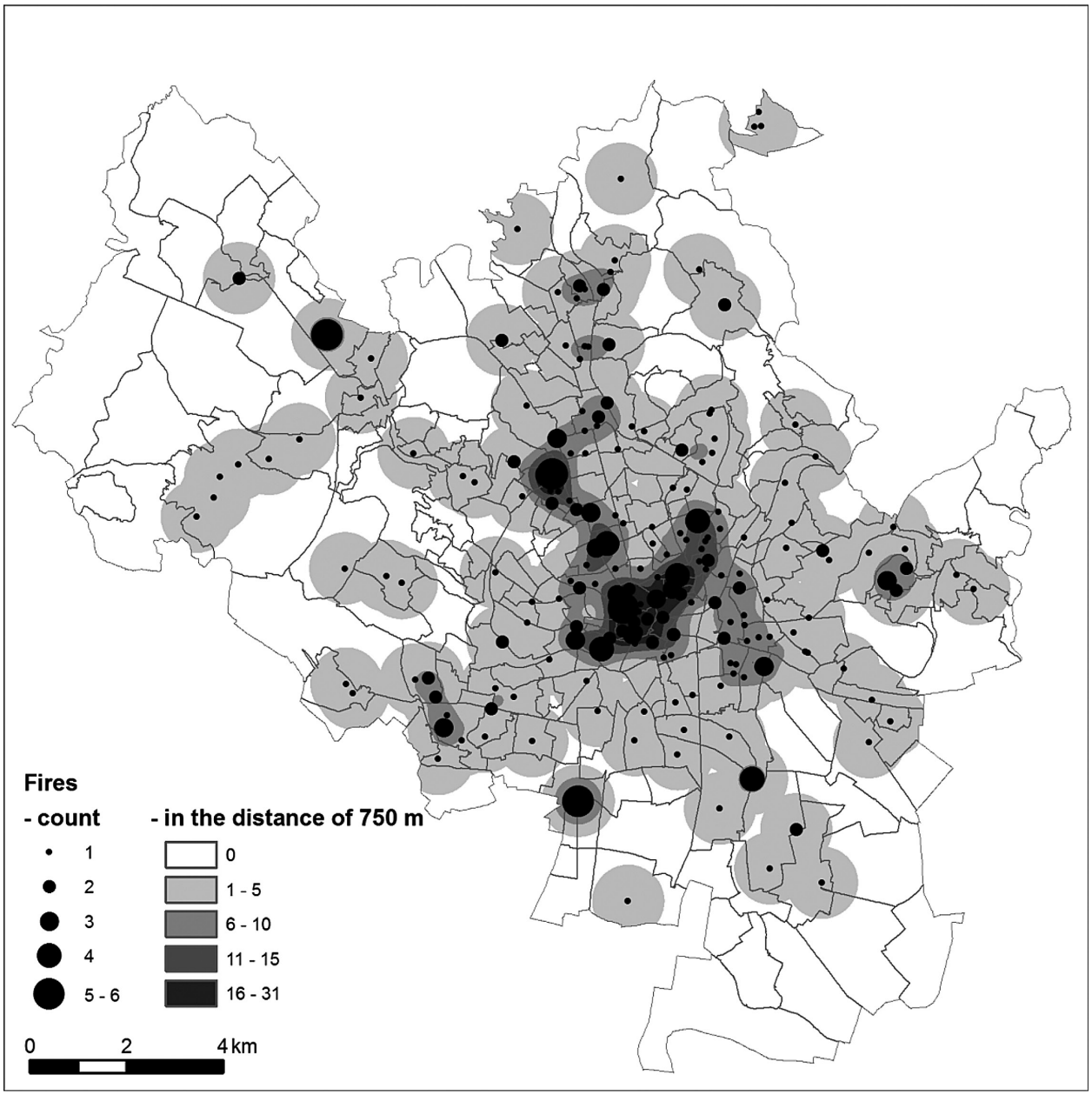

Fig. 5. Fires – kernel density

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013 and ARCDATA Praha, 2013

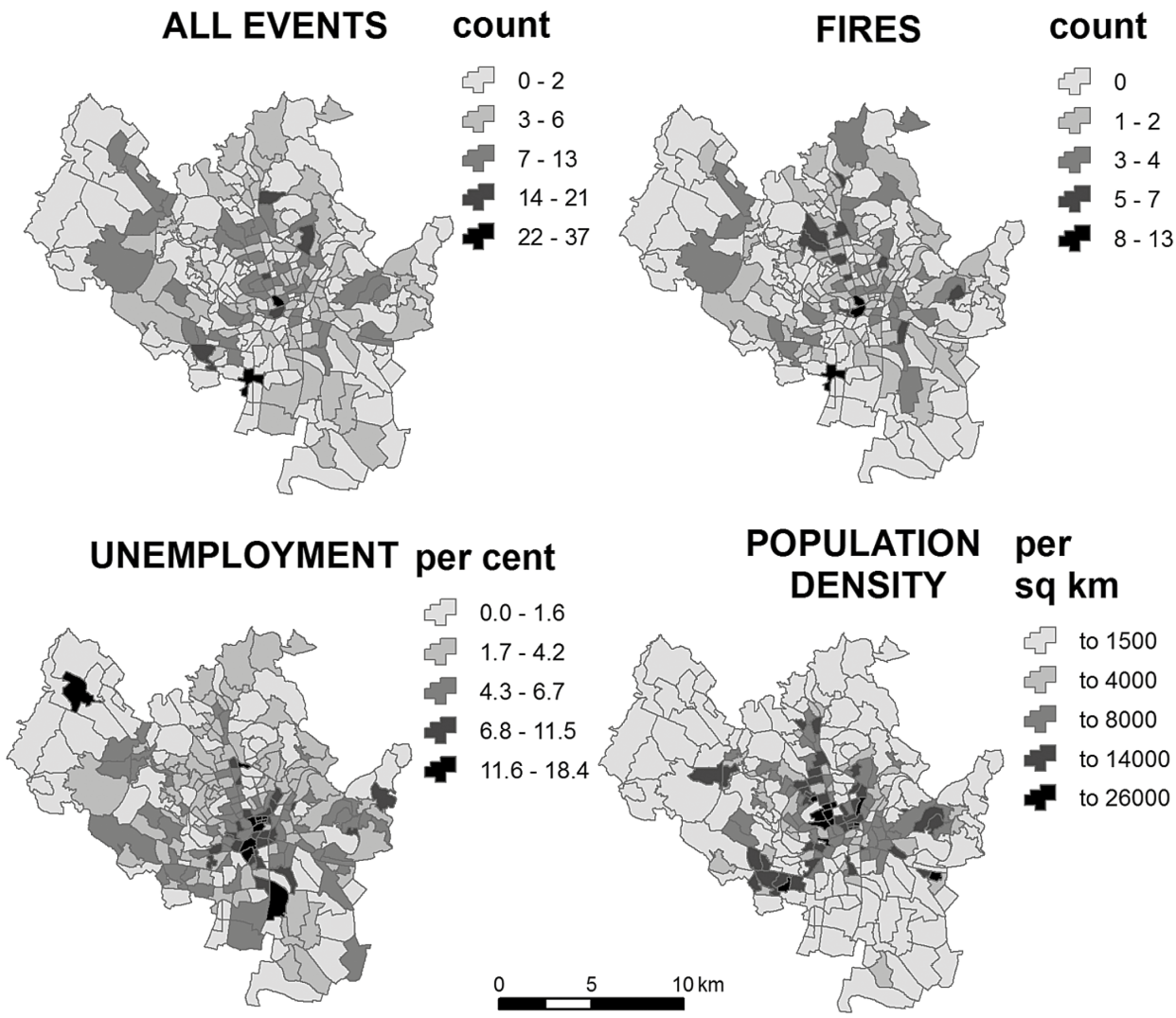

Fig. 6. Fires and socioeconomic characteristics

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013 and ARCDATA Praha, 2013

When focusing on the "fires of buildings" category we observed some similarities to fires as a whole. Obviously, there is a relation between the state of a building and fire frequency. We expected concrete high-rise blocks to be more vulnerable to fire events, but our assumption was not correct, as can be seen in the Fires of buildings map (Fig. 7.). The map shows a concentration of fires in the center and therefore we expect that fires of buildings correlate more with the characteristics of inhabitancy such as population density or wealth of inhabitants. A higher number of building fires correlates with the "problem" areas of Brno, with a worse social structure and older brick buildings. Fires of flats in housing estates in the outskirts are much less frequent.

Concerning the other chosen category "fires of forest and grass" – there is a relatively high rate of fires in recreational sites such as Brno dam (Bystrc) or other parts of the city that are still of rural nature (Mokrá Hora). This is caused by the seasonal increase of population in the case of Bystrc, espe-

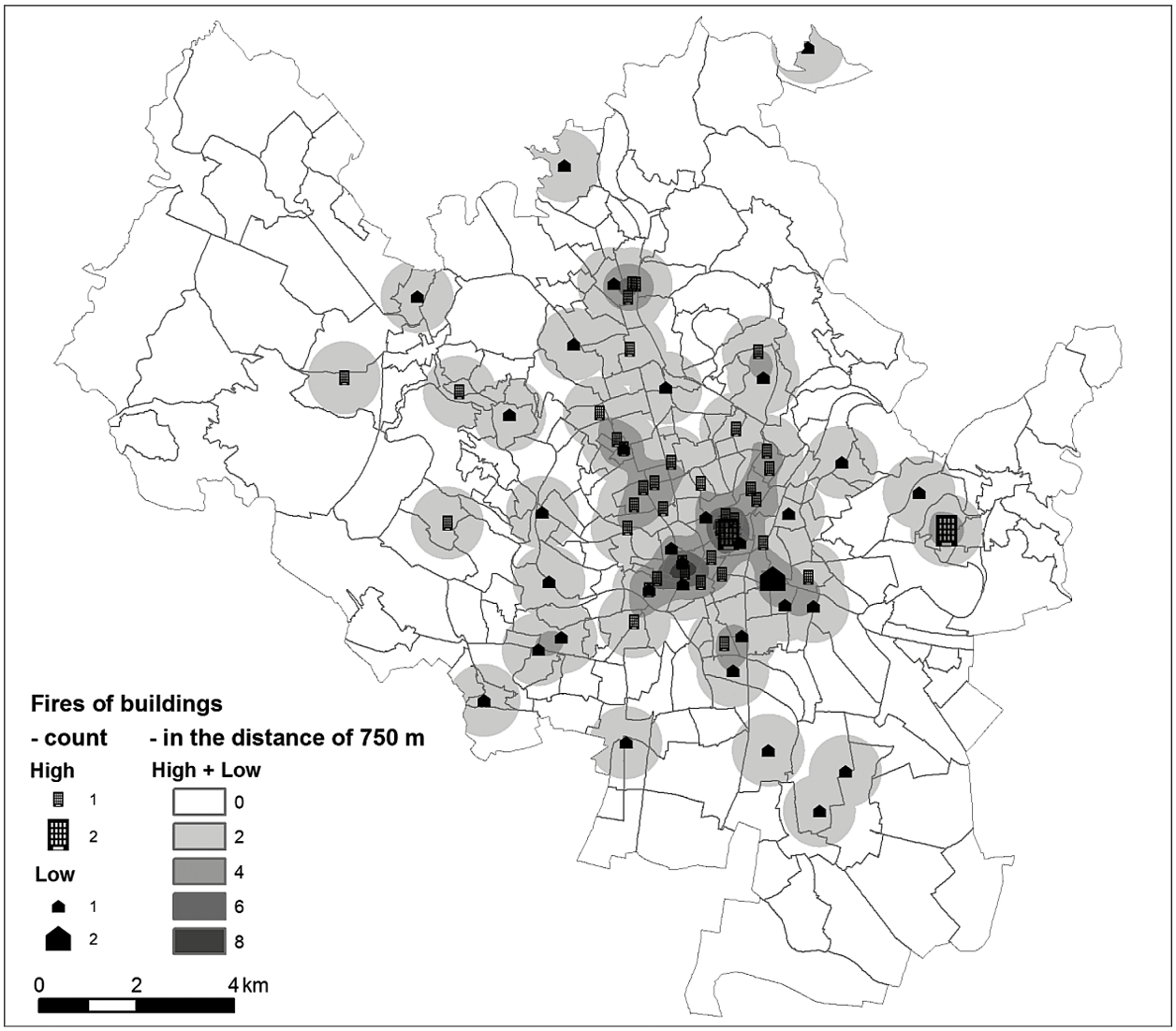

Fig. 7. Fires of buildings

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013 and ARCDATA Praha, 2013

cially in summer months (with additional risk factors such as alcohol or drugs) and by different risk factors such as burning the grass in the gardens of Mokrá Hora.

The third category is "fires of waste". Fig. 8 displays an apparent linkage between population density and count of events, but it is not as strong as in the categories "fires of buildings" or fires as a whole. Actually, other hidden variables are not so easily quantifiable. For example, the count of waste containers has a certain impact, but unfortunately we are not able to access such data. A high frequency of fires of waste in a particular location can also indicate an action of an arsonist. Fig. 8 shows an unexpected concentration of fires in Žabovřesky city part that is composed of prefab panel houses. If we zoom to higher detail, the map will show concentration in one particular street.

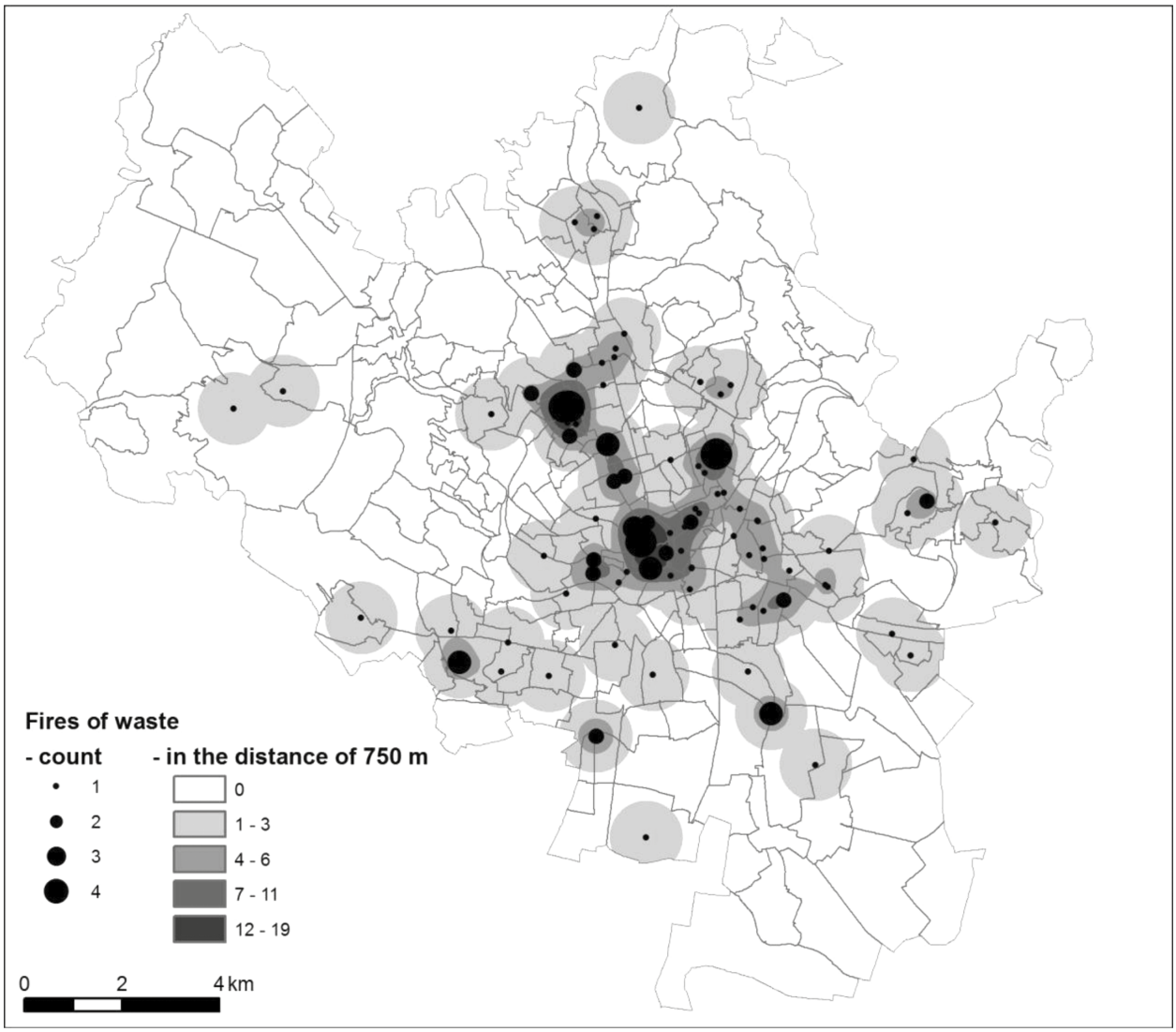

Fig. 8. Fires of waste

Source: Developed by the authors based on data from The Fire Rescue Service Brno, 2013 and ARCDATA Praha, 2013

4. Discussion

To repeat the procedure in similar settlements it is important to acquire data about a sufficient number of events including the exact location and identification within the category of fire events. The result depends on the quality of the data and on the correct categorization. There is no chance to discover the set of causes for a category listing, for example, fires of high buildings together with grass fires. As all events in the category of high buildings are very diverse, with multiple causal factors, we need huge data to perform valid statistical research. The key aspect of this methodology was a study of places with a higher occurrence of events using the methods of spatial statistics and kernel density estimation together with the expert interpretation of the structure of the city.

It is also necessary to consider the limitations of geostatistics. Geostatistical models often do not adequately consider qualitative indicators like psychological space relationships, information, flows, the actors, their behavior or thinking. Therefore, it is necessary to know the local conditions, to have an expert view, to be aware of data limitations, and to be familiar with the problem of perception and representation of geographic reality.

Engineering approach of GIS with statistical methods of data processing, kernel density, togeth-

er with the underlying layers of other characteristics (density, social status) is, however, necessary to combine with knowledge about space and place.

The collected data did not deliver an explanation of the causes, because the diversity of causes is immeasurable. We discovered that building fires and waste fires are found in areas with higher density, but other characteristics are not as provable.

A slightly segregated part of the town (around streets Cejl and Bratislavská), with a higher frequency of fire events, is tied with lower social standards, older equipment, higher unemployment, but also with the highest population density in the city. We cannot prove which of the factors is the key one and whether only these factors in these events play such an important role.

A deeper analysis of fire situations (people involved in the accident and the conditions that played a role) shows strong diversity and therefore the results cannot provide clear dependence on other phenomena. In this context, collaboration between experts at fire events and scientists who can provide the imaging and geographic representation for optimal evaluation of the situation is very fruitful.

5. Conclusion

Geographical modelling of fire events provides a very useful technique to display many events on the map and gain knowledge about their causes, which is useful for more efficient actions of fire rescue services. It is important to separate different types of fires and make research with a high number of events for detecting causes of fires.

Crucial findings concerning fires in Brno:

- fires of high buildings are more concentrated in places with high population density and places with lower social status and higher unemployment,
- fires of waste are also concentrated in the center of the city and in the panel housing estate Žabovřesky,
- generally, fire events are less common in places with higher social status, lower concentration of population (family houses); the only exception to this rule is the relatively high rate of fires in recreational sites such as Brno dam (Bystrc) or parts of the city that are still of rural nature (e.g. Mokrá Hora). These exceptions are caused by the seasonal increase of population density in the case of Bystrc and by different risk factors such as burning the grass in the gardens of Mokrá Hora,
- to gain more precise results it is essential to involve another type of data (field research, discussion with firefighters).

However, it is necessary to consider the restrictions of geostatistics and realize that fires are caused by multiple/various reasons. To verify the results discovered in this work, close collaboration with the FRS is necessary.

Higher concentration of , for example, waste fires in certain locations (in winter explained mostly by the activity of the homeless) should be useful for police prevention. The city government should therefore deal with much deeper causes which lead to fires. Generally, maps of problem areas provide governmental authorities with more information about risk areas and allow a more efficient allocation of resources – for preventing, planning and also for creating effective strategies for territorial development which will be more focused on those risk areas.

Acknowledgements

Financial support: MUNI/A/0952/2013 Analysis, evaluation, and visualization of global environmental changes in the landscape sphere.

The article has not been published before and is in accordance with the anti-ghostwriting policy of the Bulletin of Geography. Socio-economic Series.

References

Asgary, A., Ghaffari, A. and Levy, J., 2010: Spatial and temporal analyses of structural fire incidents and their causes: A case of Toronto, Canada. In: *Fire Safety Journal*, Vol. 45, No. 1, International Association for Fire Safety Science, pp. 44–57.

ARCDATA Praha, 2013: ArcČR 500, Available at: http://www.arcdata.cz/produkty-a-sluzby/geograficka-data/arccr-500/

Cannon, T., 1994: Vulnerability analysis and the explanation of "natural" disasters. In A. Varley (ed.) *Disasters, development and the environment*, Chichester: John Wiley.

Chhetri, P., Corcoran, J., Stimson, R. I. and Inbakaran, R., 2010: Modelling potential socio-economic determinants of building fires in South East Queensland. In: *Geographical Research*, Vol. 48, No. 1, Wiley, pp. 75–85.

Corcoran, J., Higgs, G., Brundson, Ch. Ware, A., and Norman, P., 2007: The use of spatialanalytic techniques to explore patterns of fire incidence: a South Wales Case study. In: *Computers, Environment and Urban Systems*, Volume 31, Issue 6, Elsevier, pp. 623––647, ISSN 0198-9715

Corcoran, J., Higgs, G., Rohde, D. and Chhetri P., 2011: Investigating the association between weather conditions,calendar events and socio-economic patterns with trends in fire incidence: an Australian case study. In: *Journal of Geographic Systems*, Vol. 13, Springer, Berlin, Heidelberg, pp. 193–226.

Czech statistical office, 2011: Sčítání lidu, domů a bytů 2011 (Population of Brno – Census 2011), Available at: http://www.scitani.cz/csu/2013edicniplan.nsf/p/12000-13

Duncanson, M., Woodward, A. and Reid, P., 2002: Socio-economic deprivation and fatal unintentional domestic fire incidents in New Zealand 1993–1998. In: *Fire Safety Journal*, Vol. 37, International Association for Fire Safety Science, pp. 165–179.

Fahy, R. and Miller, A., 1989: How being poor affects fire risk. In: *Fire Journal*, Vol. 83, No. 1, pp. 28–30.

Giddens, A., 1999: Runaway World: How Globalisation Is Reshaping Our Lives, Profile Books, London.

Grano, O., 1981: External influence and internal change in development of geography. In: Stoddart, D.R. (ed.): *Geography, Ideology and Social Change*. Blackwell, Oxford.

Jennings, C. R., 2013: Social and economic characteristics as determinants of residential fire risk in urban neighborhoods: A review of the literature. In: *Fire Safety Journal*, Vol. 62 (PART A), International Association for Fire Safety Science, pp. 13–19.

Janata J., Hladík V. and Kozák J., 2009: Požáry v českých zemích (Fires in Czech lands – in Czech), Praha: Professional Publishing, 99 p. ISBN: 978-80-86946-96-2.

Krisp, J. M., Virrantaus, K. and Jolma, A., 2005: Using explorative spatial analysis to improve fire and rescue services. In: Van Oosterom, P., Zlatanova, S. & Fendel, E. M. (Eds.): *Geoinformation for disaster management*, Springer, Berlin, Heidelberg, pp. 1283–1296.

Krömer, A., Musial, P. and Folwarczny, L., 2010: Mapování rizik (Mapping of risks). 1. vyd. Ostrava: Sdružení požárního a bezpečnostního inženýrství, 126 p.

Pelling, M., 2003: *The vulnerability of cities: natural disasters and social resilience.* ebook edn, Earthscan Publications, London; Sterling, VA.

Řihák, J. and Veselý, O., 2012: Streetalert mobile application, Available at: http://www.streetalert.cz

Sjöberg, L., 1999: Risk perception by the public and by experts: A dilemma in risk management. Human Ecology Review, 6(2), 1-9.

Skalská, K., Hanuška, Z. and Dubský, M. 2010: Integrovaný záchranný systém a požární ochrana (Integrated Emergency System and Fire Protection – in Czech). 1. vyd. Praha: MV – generální ředitelství Hasičského záchranného sboru ČR. 44 p. ISBN 978-80-86640-59-4.

The Fire Rescue Service Brno, 2013: Fire brigade actions, Available at: http://www.firebrno.cz/rss/udalosti

Wisner, B., Blaikie, P., Cannon T. and Davis I., 2005: At Risk: Natural Hazards, People's Vulnerability and Disasters, Routledge, 2nd edition.

Wallace, D. and Wallace, R., 2001: A Plague on Your Houses: Home New York was Burned Down and National Public Health Crumbled. Verso, New York.

Ministry of Science and Higher Education
Republic of Poland

The proofreading of articles, positively reviewed and approved for publishing in the 'Bulletin of Geography. Socio-economic Series', was financed from the funds of the Ministry of Science and Higher Education earmarked for activities popularizing science, in line with Agreement No 509/P-DUN/2016.