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SPATIAL ANALYSIS OF FIRES IN VILNIUS CITY IN 2010–2012

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Abstract. The paper describes the results of investigation into urban fires in the city of Vilnius, Lithuania in the three-year period of 2010–2012. Cartographic and geospatial analysis of fires is needed due to dynamism of this phenomenon, risks for inhabitants, importance to city's socio-economic development and lack of geographic approach to research of urban fires in Lithuania. The registered fires were mapped and grouped by their type (abandoned building fires, open space fires, fires in tower blocks of flats, garbage can fires, vehicle fires and arsons), cause, location type (open space and premises) and by fatality rate. Spatial distribution of fires at different scales was analysed using cartographic method and spatial analysis with GIS. Some unexpected patterns have been revealed, analysed and compared with building materials that dominate in different areas of the city. It was found out that relative frequency of fires depends on complex parameters of socio-demographic environment whereas constructional materials have little or no impact. We expected to observe a relationship between criminal activities and fires due to similar influencing socio-demographic factors. Positive correlation, though insignificant, supported this hypothesis. The study showed that fire distribution patterns may be very specific for an individual city and difficult to explain by general assumptions. Different methods of spatial, statistical and cartographic analysis must be combined in order to make reliable generalisations.

Keywords: urban fires, spatial distribution, constructions, constructional materials, crimes.

Introduction

First investigations on urban fires started in the USA in the 1980s. They mainly concentrated on impact of demographic and socio-economic factors on fire risk. (Sternlieb, Burchell 1973; Bertrand, Lawrence 1976; Karter *et al.* 1977, 1978; USFA 2004, 2009). 21st century brought more studies in Europe (Corcoran *et al.* 2007a, 2007b; Špatenkova, Stein 2010), Asia (Urban Research Institute 2004; Nisanci 2010; Zhao 2011; Lu *et al.* 2013), Australia (Corcoran *et al.* 2009; Chhetri *et al.* 2009; Sufianto, Green 2012). A number of them applied spatial and temporal analysis and resulted in prognostic maps (Corcoran *et al.* 2009; Wu 2007; Rohde *et al.* 2010; Zhao 2011) and mathematical models (Wu, Ren 2009; Ceyhan *et al.* 2013; Zhang 2013).

Analysis of location and dynamics of fires allows for revealing the trends of spatio-temporal concentration of fires (Corcoran *et al.* 2009). Based on this information more efficient prevention strategies and measures can be applied thus saving money and lives (according to official statistics of Fire and Rescue Department 3065 persons died and 3112 were injured in Lithuania during the analysed three-year period). Urban fires are as often as the countryside fires but the major causes are different: the most of the fires in countryside are caused by improper electric installation and ovens, lightning whereas urban fires strongly depend on social factors. Urban fires in Vilnius, although they only comprise about 15% of all insurance events, cause biggest damage to households and often result in fatalities. The number of fires in the city does not decrease: we have analysed 1506 events in 2010, 1715 events in 2011 and 1303 events in 2012. In the research carried out in early 2013 we attempted to identify the most problematic areas at the scale of city (500×500 meter cells) and to analyse the structure of fires in those areas at larger scale.

Different researchers have identified some common factors that influence the risk of fires. Munson (1976) has demonstrated almost linear dependence

between the number of fires and population density and reverse linear dependency between the number of fires and household income. Although it was based on small number of events, later research confirmed those two factors, especially the level of income (Gunther 1981; Munson, Oates 1983; Fahy, Norton 1989; Jennings 1996; Špatenkova, Stein 2010). The other social factors that doubtlessly have impact on increased risk of urban fires are: high unemployment rate (Munson, Oates 1983; New South Wales Fire Brigades 1997; Chhetri *et al*. 2009); high percentage of incomplete (one parent) or unstable families (Schaenman *et al*. 1977; Karter *et al*. 1978; Jennings 1996; Leth 1998; Chhetri *et al*. 2009); low level of education (Schaenman *et al*. 1977; Munson, Oates 1983; Corcoran *et al*. 2011); age of population especially the rate of very young (Runyan *et al*. 1993; New South Wales Fire Brigades 1997; Chhetri *et al*. 2009) or elderly people (Jennings 1996).

Later studies (Yamashita 2008; Špatenkova, Stein 2010) revealed some significant factors related with urban environment: technogenic development, age and type of buildings and ratio of parcels without owners; and temporal variations (Corcoran *et al*. 2007a, 2009).

Some authors have determined dependencies between frequency of fires and characteristics of urban communities. Hall (1993) stated that there exists a non-linear dependence: both small and large communities are exposed to higher fire risk than average size communities (likely due to hypothetically lower rate of inhabitants with low income in the latter). As our data showed some concentrations of fires unexplained neither by population density nor by above listed factors alone, we analysed them against two other phenomena that could possibly have impact on fire risk: prevailing constructional materials as urban environment criterion and crime rate as a social criterion. Both datasets were analysed with absolute and relative (number of fires per 1000 inhabitants) fire density grid data and spatial dataset of registered fire events.

1. Fires in Vilnius in 2010–2012

The 4524 fires in Vilnius City in 2010–2012 have been uniformly registered with the following attributes: full date, time (hour and minutes) address, type of object, cause of fire, number of saved people and number of fatalities. The data were geocoded and for comparison purposes generalised by statistical grid at resolution 500×500 meter. Relative number of fires was calculated using the data of officially registered residents for the address points. The fires in open areas comprise 26.5%, garbage container fires – 18.4%, fires in tower blocks of flats – 18.1%, vehicle fires – 13.5%, fires in abandoned buildings – 8.7% and fires in private houses – only 4.1%. The main reasons of fires are: negligence (70.3 %), arsons (7%) and faults of electric installations (buildings – 6.5% and vehicles – 6.2%).

General fire density maps look very similar to population density maps, though correlation between the number of residents and residential fires is barely significant (r = 0.55). It was unexpected to observe correlation between the number of residents and open space fires is (r = 0.36).

Number of fires per 1000 inhabitants shows different pattern (Fig. 1), not very different from the pattern of fires per building (*kc.gf.vu.lt/Publikacijos/Gaisrai/BuildingFR.jpg*). We assume that larger zones where the concentration is much higher than average reflect abandoned buildings are characterized either by high percentage of abandoned buildings/flats, like those in at Vilnelė river and (or) by communities/families at risk, like Naujininkai and the permanent gypsy camp or particular suburban residential cottage areas.

The temporal patterns are also clearly distinguishable and very similar for each year *(kc.gf.vu.lt/Publikacijos/Gaisrai/FireByTime.jpg*). Significantly more fires occur in April (most likely related to dry weather conditions and burned grass) and in October–November when the heating season starts and most of extra fires are due to improper use and (or) faults of heating equipment. The 'worst' are the afternoon hours, mainly after 14 PM whereas low numbers of fire incidents are registered between 5 and 10 AM. Among days of the week, significantly more events occur on Sundays

Different types of fires occur in the districts of the city with different characteristics. It can be demonstrated by the location quotient maps (*kc.gf.vu.lt/Publikacijos/Gaisrai/LQs.jpg*). Typically prevailing fire incidents are related with the dominance of specific target territories: blocks of flats, open (but not recreational) spaces, abandoned buildings. Fires in garbage containers prevail in districts with lower social standard (e.g., Šnipiškės, Naujamiestis) and the central districts where they may be due to higher number of homeless people. Arsons dominate in the rather prestigious districts of Žvėrynas and Antakalnis. Considering this, different fire prevention measures should be planned in those districts. There is a single zone where deconcentration of fires was observed in the northern part of Naujoji Vilnia that could be explained by improving socio-economic environment in this district.

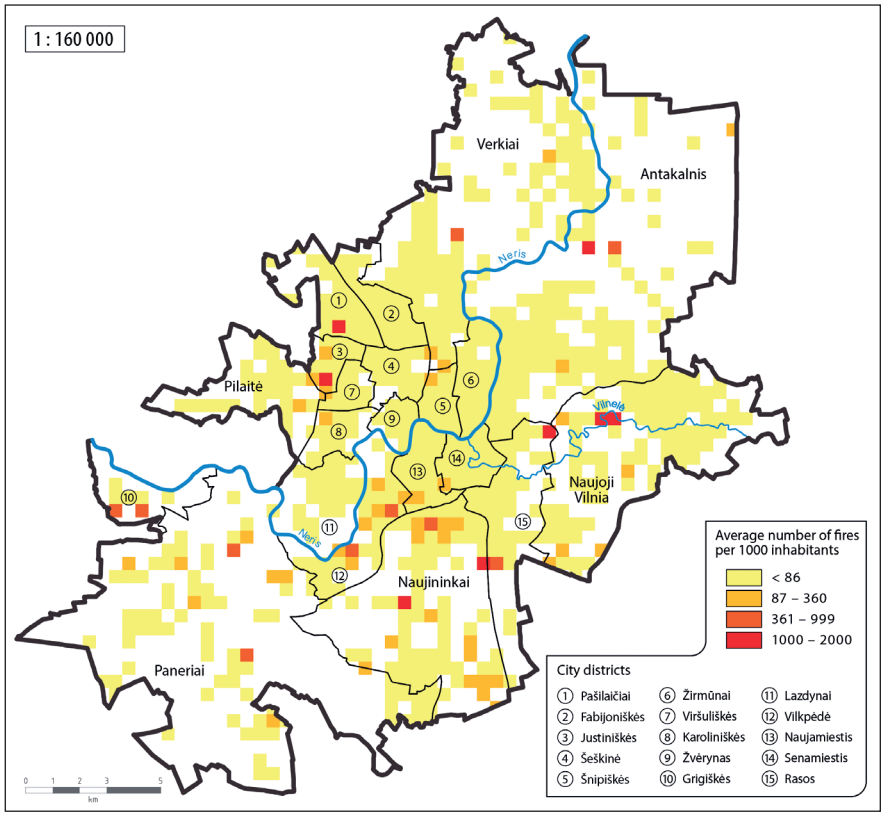

Fig. 1. Average number of fires per 1000 inhabitants in 2010–2012

2. Fires and crimes

Based on hypothesis that both criminal activity and fires reflect a whole complex of social factors, we combined fire data with data on registered criminal events registered during 2012, provided by the Vilnius police authorities. Criminal incidents that are presumably not related to the urban environment (e.g., forgery, bribery, tax evasion, unauthorized access to information etc.) were excluded and the remaining 2063 incidents were grouped by the type of environment: open spaces and other public areas; residential premises; non-residential premises. Even though both criminal incidents and fires expectedly strongly depend on similar socio-demographic reasons, correlation between them in the territory of Vilnius reaches only 0.44 (cells without fire incidents are ignored) that is not significant. Correlation between fires and all registered events that have not been qualified as criminal incidents (noise, minor vandalism, harassment etc.) is slightly higher – 0.51 (cells without fire incidents are ignored).

The map (Fig. 2) depicts the ratio of fire and crime events. It shows the 'central' cluster of lower fire-to-crime rate in densely populated city areas. There are some spots of higher than average concentration of both crimes and open space fires (e.g., at the border of Fabijoniškės, Šeškinė and Pašilaičiai) and that may indicate activities of youngster gangs. The cells with higher than average ratio, caused by other than demographic factors, are scattered in the peripheral districts. There are two main types of them: areas that contain higher percent of non-residential constructions and abandoned buildings and small residential cottage areas with unsafe neighbourhood. Garbage container fires dominate in such cells close to the centre. In some densely populated cells where garbage container fires occur systematically (mainly due to vandalism and negligence), plastic containers should be replaced by metallic ones.

3. Fires and constructional materials

Digital database of constructional materials of Vilnius buildings has been compiled based on realty register data and on data provided by Vilnius municipality (Jukna 2014). Vilnius city consists of variety of relatively homogeneous zones where at least 60% of buildings are built using the same basic constructional material: brick constructions in the Old Town (20.7%), surrounded by the concrete blocks of flats of 1970s–1980s (34.8%), wooden house mainly in districts in Žvėrynas, Antakalnis and Naujoji Vilnia (16.9%); scattered peripheral newer

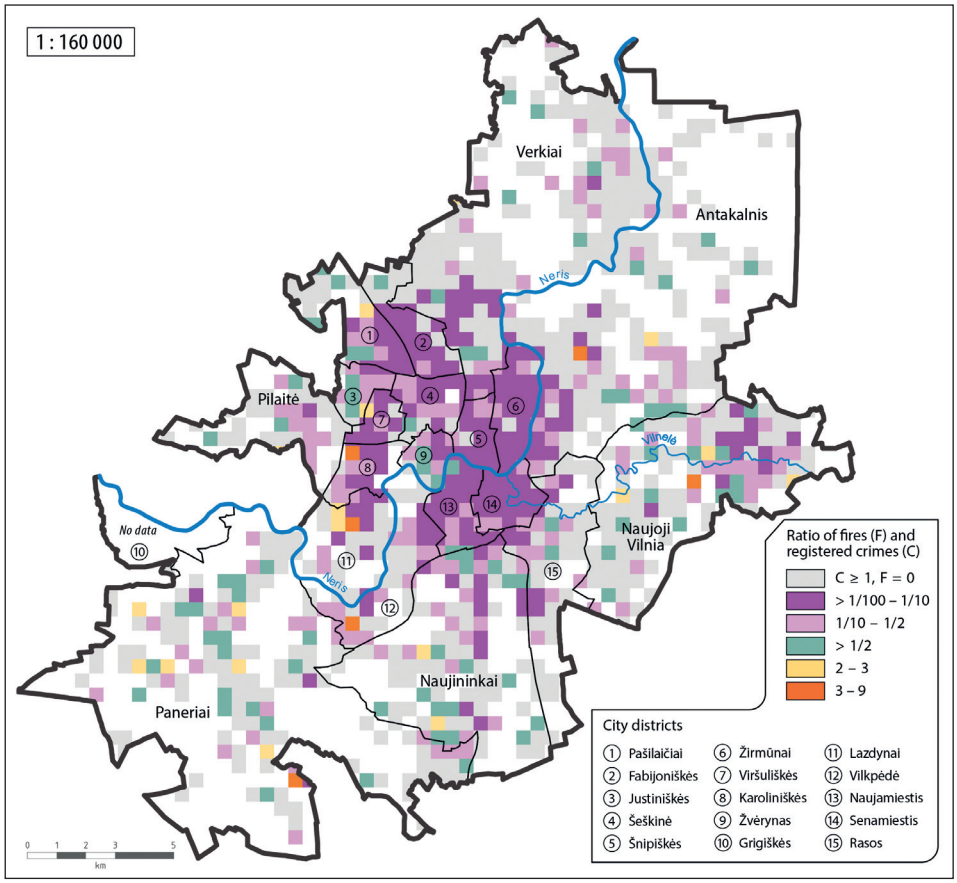

Fig. 2. Fires vs. registered crimes in 2012

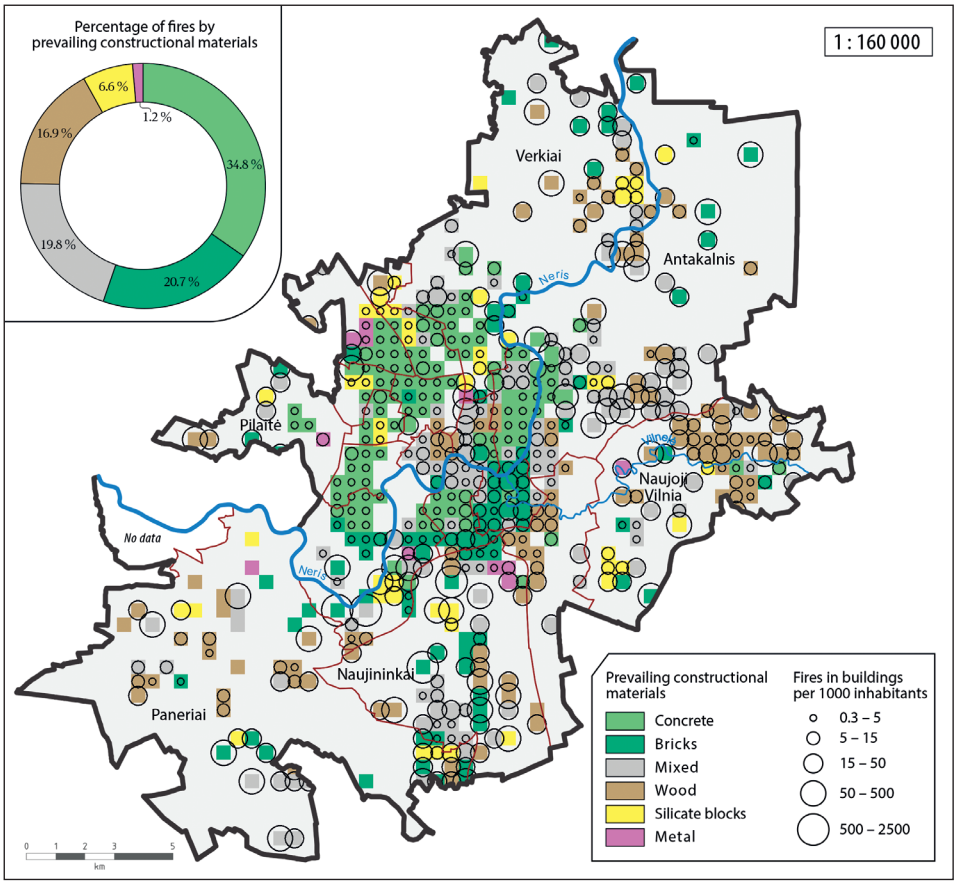

Fig. 3. Fires vs. constructional materials in 2010–2012

silicate block areas and 19.8% of 'mixed' areas (two or three materials, at least 25% each).

The chart (Fig. 3) demonstrates that relative number of fires is much lower in the concrete and silicate block areas. More fires per resident occur in areas of older brick dwellings and even more, as it could have been expected, in the areas with prevailing wooden constructions – both with high percentage of dilapidated buildings without central heating. It is often believed that arson is most common cause of fires in the 'wooden' districts of Vilnius, but the data does not confirm it.

Fires in the mixed type built-up areas are not directly related to the number of residents, they often occur in warehouses, abandoned buildings etc., but very rarely in metallic constructions.

4. Other insights and conclusions

Urban fires in the city of Vilnius occur in similar yearly spatial and temporal patterns. Number of fires depends on various technological, socio-demographic and environmental factors that are interrelated. Therefore it is practically impossible to determine impact of a single factor, but GIS analysis allows to identify territories at risk and to make assumptions about the reasons that is necessary for efficient fire prevention.

Fire incidents in Vilnius are related with population density and urbanization level. Number of permanent residents significantly influences the number of residential fires in densely populated districts and much less in larger industrial districts. It was a surprise to find out that the number of fires does not correlate with the density of buildings in Vilnius, but some negative correlation is observed in some districts i.e., less fires occur in densely built-up parts of Karoliniškės ($r = -0.61$), Žvėrynas and Pilaitė ($r = -0.41$). Considering the diversity of the three districts (old and new private houses of Žvėrynas, soviet blocks of flats of Karoliniškės and new blocks of flats in Pilaitė), it could only be explained by presence of small active communities preventing residential fires in those districts.

Location quotient maps show general dependence between percentage of target territories / social groups and number of fire incidents. It should be noted that the biggest numbers of fires that are due to negligence are evenly close to average in all the districts.

Hot-spot analysis shows four significant (99.7%) clusters with increasing risk of fires (*kc.gf.vu.lt/Publikacijos/Gaisrai/HotSpots.jpg*): two residential areas where most of fires occur in flats and garbage containers (western part of Karoliniškės and northern part of Justiniškės) and two industrial areas in Naujininkai (mainly fires in open areas and abandoned buildings). Some of the hot-spots may be explained by proximity to specific objects, or, in contrast, by peripheral location.

As it was demonstrated by our research, the assumptions drawn from data not only support but also may contravene common beliefs and hypotheses about risk and reasons of urban fires. Further detailed analysis of detected territorial anomalies is necessary in order to integrally understand fire patterns in each individual city.

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