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FIRE HAZARD AND FIRE RISK ASSESSMENT OF URBAN AREAS IN NORTH MACEDONIA

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Fire risk analysis in urban areas is a critical component of urban planning and safety management. It involves assessing the likelihood of fires occurring and the potential impact of those fires on people, property, and the environment. First step is identification of fire hazard. This step involves identification of potential sources of ignition and fuel sources. Next step is assessment of vulnerable assets. Urban areas contain various assets that may be vulnerable to fire, including residential buildings, commercial properties, industrial facilities, transportation infrastructure, and critical facilities such as hospitals and schools. Fire risk analysis involves assessing the vulnerability of these assets to fire and the potential consequences of damage or loss. Evaluation of Fire Spread means understanding how fires may spread within urban areas. It is crucial for assessing fire risk. Factors such as building density, construction materials, urban layout, and prevailing weather conditions can influence the spread of fire. Fire risk analysis also considers the effectiveness of fire prevention measures and emergency response capabilities in urban areas. This includes evaluation of the availability of firefighting resources, the adequacy of fire detection and alarm systems, access to water supplies, and evacuation plans. In addition to assessing physical risks, fire risk analysis may also involve evaluating the vulnerability of specific communities within urban areas. Factors such as socioeconomic status, demographic characteristics, and access to resources can influence the ability of communities to prevent, mitigate, and recover from fires. Overall, fire risk analysis in urban areas is essential for enhancing community safety, protecting property and infrastructure, and promoting sustainable urban development. By understanding and mitigating fire risks, cities can become more resilient to fire-related disasters. This paper presents the results of the fire risk analysis of the urban areas in North Macedonia. Population density and build-up density significantly affect the fire risk. Due to its dense built-up area, Skopje has the highest fire incidence compared to Struga, Gostivar and Strumica.

Keywords: fire, hazard, risk, risk assessment, urban areas, urban planning

1 INTRODUCTION

Every year, more than 180,000 people die in fires or from burn-related injuries worldwide. Over 95% of these deaths and injuries occur in low- and middle-income countries, where risks rise in proportion to rapid urbanization. Low-income countries, for example, have seen a 300% increase of fire incidents in built-up areas. Inadequate planning, infrastructure, and construction practices related to fire prevention and mitigation significantly increase the potential for conflagration, fire ignition and spread. Fire risk reduction requires articulated institutional measures to strengthen fire suppression capability, education and training. Proven approaches through building and fire regulation include appropriate enabling legislation; well-designed and implemented building and fire regulations; and adequate capacity to undertake building fire safety plan reviews and construction inspections [1].

However, formal regulation alone is insufficient to tackle this challenge. Informal settlements, where an estimated 25% of the world's urban population live, are often out of the formal regulatory scope and particularly at risk due to several factors such as high population density, overcrowding, highly combustible building materials and lack of water infrastructure [1].

Fire safety has been a historical cornerstone of building regulation, evolving to address mitigation for safer, more accessible buildings. The value of such safety measures has also been reinforced by the serious risk that fires pose to the environment and public health. A wide range of codes and standards have become available to facilitate fire-safe structures and build more resilient communities. However, for this knowledge to be adequately implemented, it needs to be adapted to the social, economic, legal, and cultural context of countries, including unregulated informal sectors.

Sustainable and inclusive building fire regulatory systems, embedded in planning and building design processes, are an essential foundation of fire risk reduction, benefiting people, property, and the economy. Through capacity building of local authorities and other relevant stakeholders, fire safety design principles can sustainably increase resilience and reduce the violent impact that fires have across urban areas worldwide.

1.1 FIRE HAZARD AND FIRE RISK IN BUILDINGS

Fire hazard in buildings can be defined as possibility of an accidental or intentional fire that can threaten lives, construction and property safety in the building. Fire and flames can cause loss of lives, injuries or other health consequences. Released toxic gases, if they become more intense, cause environmental degradation. The need for rehabilitation of burned buildings leads to social and economic damage to the families that were affected by fire, and if it is a fire in a commercial or industrial building, work is interrupted in the execution of activities and huge financial losses are caused.

The term “risk” has two different meanings. First, as a synonym for probability of a harmful effect occurring and second, as a synonym for the mathematical expectation of the magnitude of the undesirable consequence, even as a quasi-synonym of consequence, whereby risk has a similar meaning to undesirable outcome [2].

2 METHODOLOGY

The fire risk in buildings is directly related to the fire hazard, exposure of the population and material goods and their vulnerability. In order to define the fire risk in buildings, a comprehensive analysis of a large number of statistical data is required, both from the aspect of fires that already have happened and the resulting consequences, as well as from the aspect of demographic data and data on the built-up density of the space [3,4]. Additionally, on-site inspection for collecting data on the real building condition is necessary. This inspection includes defining the quality of the building and the materials used, the number of floors, level of timely caused degradation and compliance with the regulations for protection against fires, explosions and hazardous materials.

There are a large number of methods and tools for assessing the fire risk in buildings [5,6,7]. The methods can be classified as qualitative, quantitative and semi-quantitative methods. The choice depends on the available data on the base on which the risk assessment is performed.

Qualitative methods assess the risk descriptively, based on subjective engineering judgment, and are usually used for quick assessment of potential fire risks and looking at various fire protection measures that need to be implemented to reduce the risk. Checklists are most often used, which represent a quick method for checking compliance with the requirements of regulations and standards. Checklists can be simple or detailed, depending on the needs.

Quantitative methods result in a quantified risk, where the risk is equal to the product of the probability of fire occurrence and the consequences of the fire, which are expressed in the form of a numerical value. The probability of a fire occurring is expressed as a frequency per unit of time, and the consequences are expressed as the number of deaths/injured or the numerical value of material loss.

Semi-quantitative methods represent a combination of quantitative and qualitative methods and can give the percentage of risk in a simple, partially quantitative way when access to data is limited.

Quantitative and semi-quantitative methods require detailed analysis, as well as the existence of appropriate statistical data for fires. Fires that have happened in the past testify to how fires spread and indicate the (in)efficiency of the measures implemented with the aim of meeting the minimum technical requirements dictated by the regulations, but the real impact on each fire protection provision or combination of provisions cannot be measured, and hence the application of quantitative methods becomes complicated.

This paper presents statistical data for four towns in North Macedonia which are basis for conducting the fire risk assessment by implementing the semi-quantitative matrix method.

2.1 Statistical data on fires in buildings

For an adequate assessment of the fire hazard in buildings in a certain settlement, it is necessary to have statistical data on the number of fires in defined period, spatial and time distribution of fires, the reason for the occurrence of fires, the urbanization of the area, the possibility of timely intervention by fire brigades, characteristics from the aspect of construction quality and fire protection measures undertaken in the buildings. In order to carry out an adequate risk assessment, it is necessary to have data on the material damages caused by the fires, the number of people injured in the fire and eventually loss of human lives.

The reason for starting a fire is the primary danger and knowing the possible initial source of heat or flame that may cause fire is very important for defining the fire hazard. Sources of ignition can be found at every workplace and in the home. From the statistical data, it is possible to identify ignition sources and the number of accidental fires related to each of the possible sources [8,9]. It is considered that the following "initiators" cause the greatest fire danger: cigarettes, lighters, electrical appliances, space heating systems, boilers, electric cables, candles, lightning strikes and other/unspecified. If the work is for production facilities, additional sources of heat at the workplace can be: electrostatic discharges, combustion furnaces or open hearths, boilers, engines with internal combustion, equipment for burning oil, equipment for welding and cutting, etc.

Depending on the characteristics and purpose of the facility, there may be a risk of more than the listed initiators for starting a fire. In addition to this classification, the causes of fire can be classified according to the sources of energy from which the fuel receives the heat. According to world statistics, the representation of energy types is as follows: thermal energy (64%), electrical energy (15%), chemical energy (11%), mechanical energy (9%), other (1%) [8,9].

The location of the fire as well as the time when the fire started are factors that should be taken into account when analyzing the fire hazard. The time domain plays a very important role in risk analysis as the distribution of fires in buildings varies depending on the time of day, day of the week, month of the year, and even season. Other very important factors that affect the fire hazard are the density of built-up space, population density and construction characteristics of buildings.

Consequences of fire are expressed as number of deaths/injured or numerical value of material losses. These statistical data are crucial for defining the fire risk. Unfortunately, not all countries in the world keep adequate statistics on all factors influencing the fire hazard and the fire risk.

The statistical data for urban fires in North Macedonia are not complete at the moment. Currently, available data are only on the number of fires in residential buildings by municipality and by month, without data on the reason for the occurrence of the fire, on the characteristics of the building that was set on fire, without an assessment of material damage. The only additional data is the number of injured or dead tenants and firefighters.

3 RESULTS AND DISCUSSION

This paper presents the analysis of the available data for the municipality of Strumica for period of 3 years (2020 - 2023). The results are compared with the data obtained for 3 other municipalities in North Macedonia: Skopje (for the period 2008-2011), Struga (for the period 2005-2020) and Gostivar (for the period 2017-2023). Based on the results of this analysis, conclusions are drawn about the factors that affect the fire risk in these 4 cities.

3.1 FIRE HAZARD ANALYSIS FOR FOUR CITIES IN N. MACEDONIA

To define the population's exposure to the risk of fires in buildings, the data for the number of fires per 10,000 inhabitants, per year, are presented. In this way, it is possible to compare the number of fires in each municipality, and in such a way it will be possible to create the fire hazard maps. For the exposure of material goods to the risk of fires in buildings, the number of fires per 10 km^2 of built-up residential area is defined. In this way the number of fires is related to the density of built-up space.

Municipality of Strumica has 161 inhabitants per km^2. 82% of inhabitants are living in reinforced concrete houses or buildings, while 18% are living in masonry houses. 50% of homes are built before 1980. and 50% after this period.

Data on fires in the municipality of Strumica were obtained from the Territorial Fire Fighting Brigade (TFFB). The number of fires in buildings, for the period 2020-2023, per 10000 inhabitants and per months, is shown in Fig. 1. It is evident that fires dominate in the winter period. According to the given data, the chimney fires are predominant. No cause was given for the other fires.

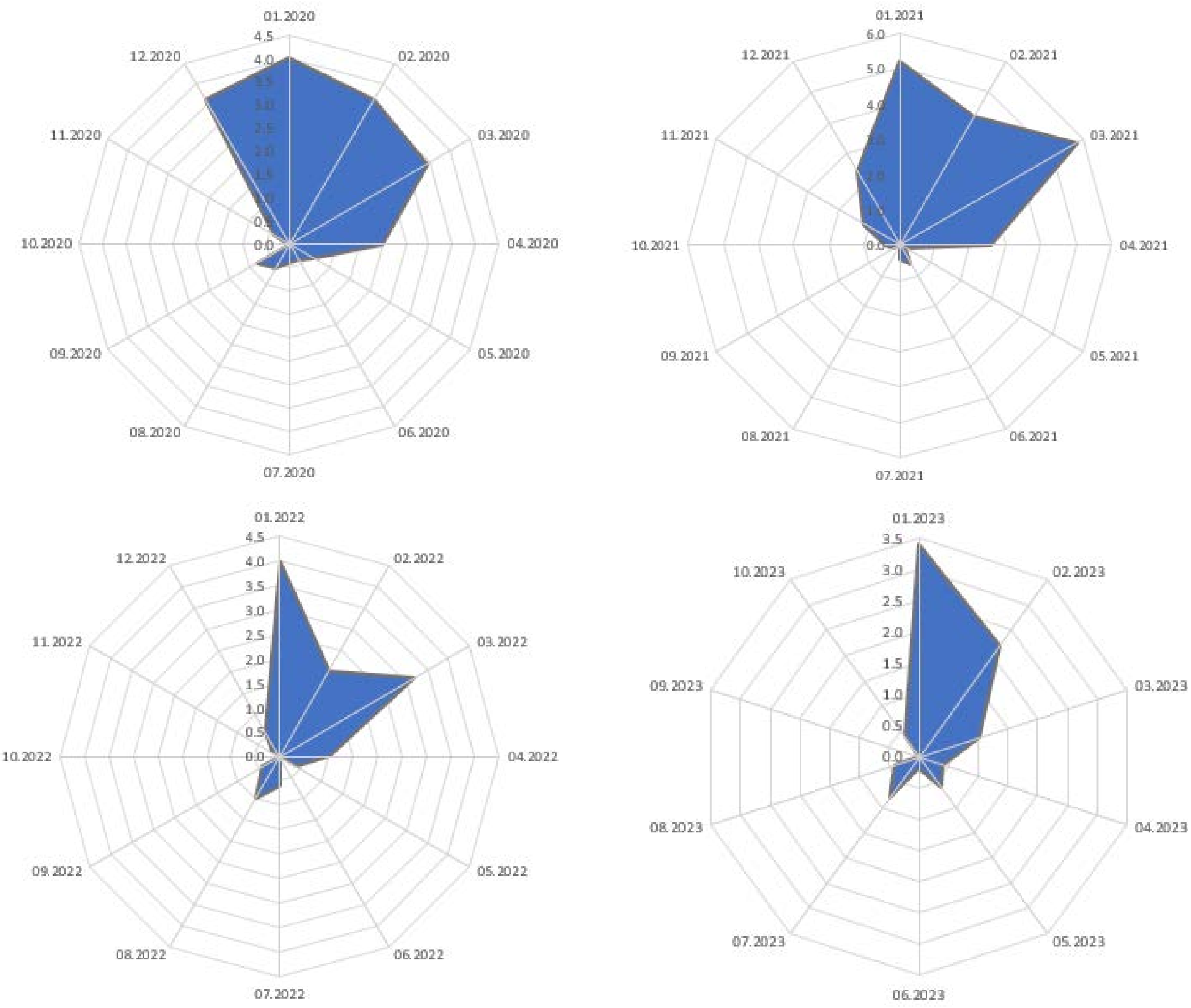

Fig. 1. Number of fires in buildings in municipality of Strumica, per months and per 10,000 inhabitants, for period 2020-2023

The increased number of fires in 2020. and 2021. coincides with the period of the Covid pandemic, when due to the lockdown the population was not able to service the chimneys and the heating units, which were mainly on solid fuel, were constantly on. The situation is similar with the municipalities of Struga and Gostivar. The central heating system is dominant in Skopje and the number of fires increased slightly during this period.

Fig. 2 presents the summary of the total number of fires in relation to 10,000 inhabitants and in relation to 10 m^2 of built-up space. In this review, the year 2023 is omitted, for which the data were not complete.

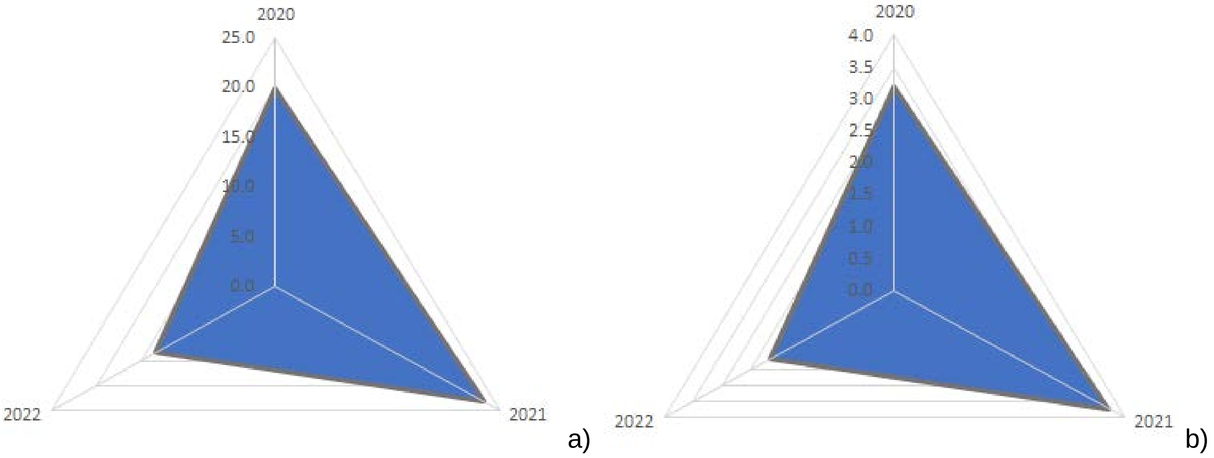

Fig. 2. Summary of the total number of fires in municipality of Strumica, in relation to: a) 10,000 inhabitants, b) 10 m^2 of built-up space, for period 2020-2022

Population density and build-up density are factors that significantly affect the fire risk, but there is a lack of data on the causes of fire. Corresponding data was also obtained for the municipalities of Gostivar and Struga, and only the aggregated data by year are shown in Fig. 3 and Fig. 4.

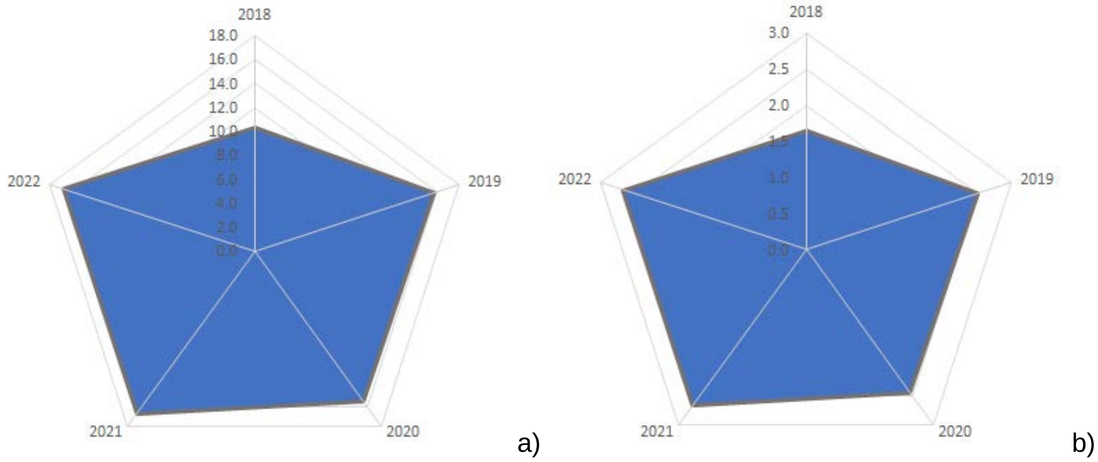

Fig. 3. Summary of the total number of fires in municipality of Gostivar, in relation to: a) 10,000 inhabitants, b) 10 m^2 of built-up space, for period 2018-2022

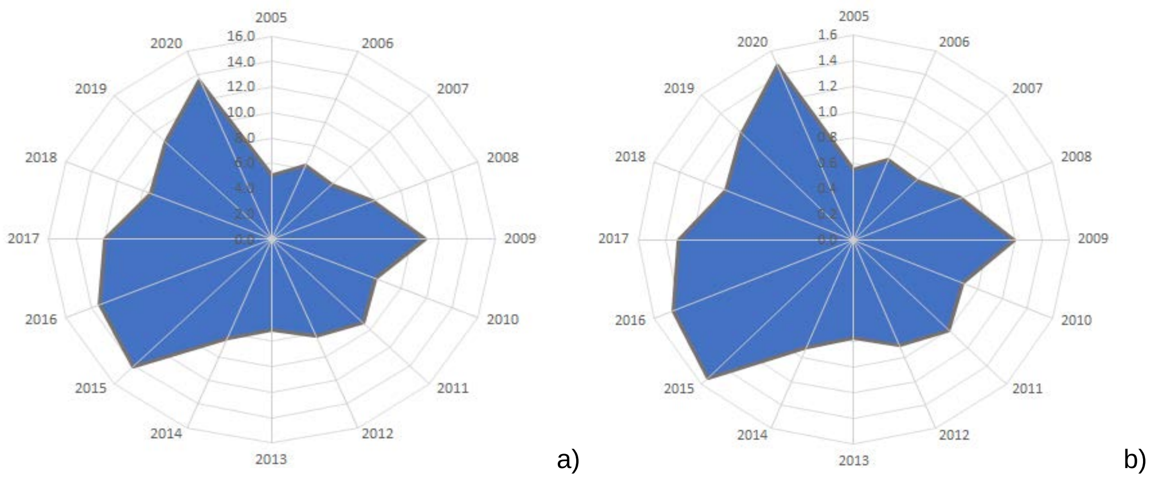

Fig. 4. Summary of the total number of fires in municipality of Struga, in relation to: a) 10,000 inhabitants, b) 10 m^2 of built-up space, for period 2005-2020

A comparison is made between the number of fires per 10,000 inhabitants and per 10 km² built-up residential area, for the municipalities for which there is a matching year (Fig. 5). It is evident that the number of fires does not depend on the number of inhabitants, but on the density of buildings in the area. The city of Skopje is characterized by the highest built-up density and the number of fires per 10 km² of built-up residential space is drastically higher.

A comparison of the average number of fires in buildings in one year in the three municipalities and the city of Skopje, expressed as the number of fires per 10,000 inhabitants and 100 km², with population density and building density, is shown in Fig. 6. It is evident that in addition to the density of buildings, the density of the population also has a large impact. Again, on both criteria, the city of Skopje has the highest exposure factor.

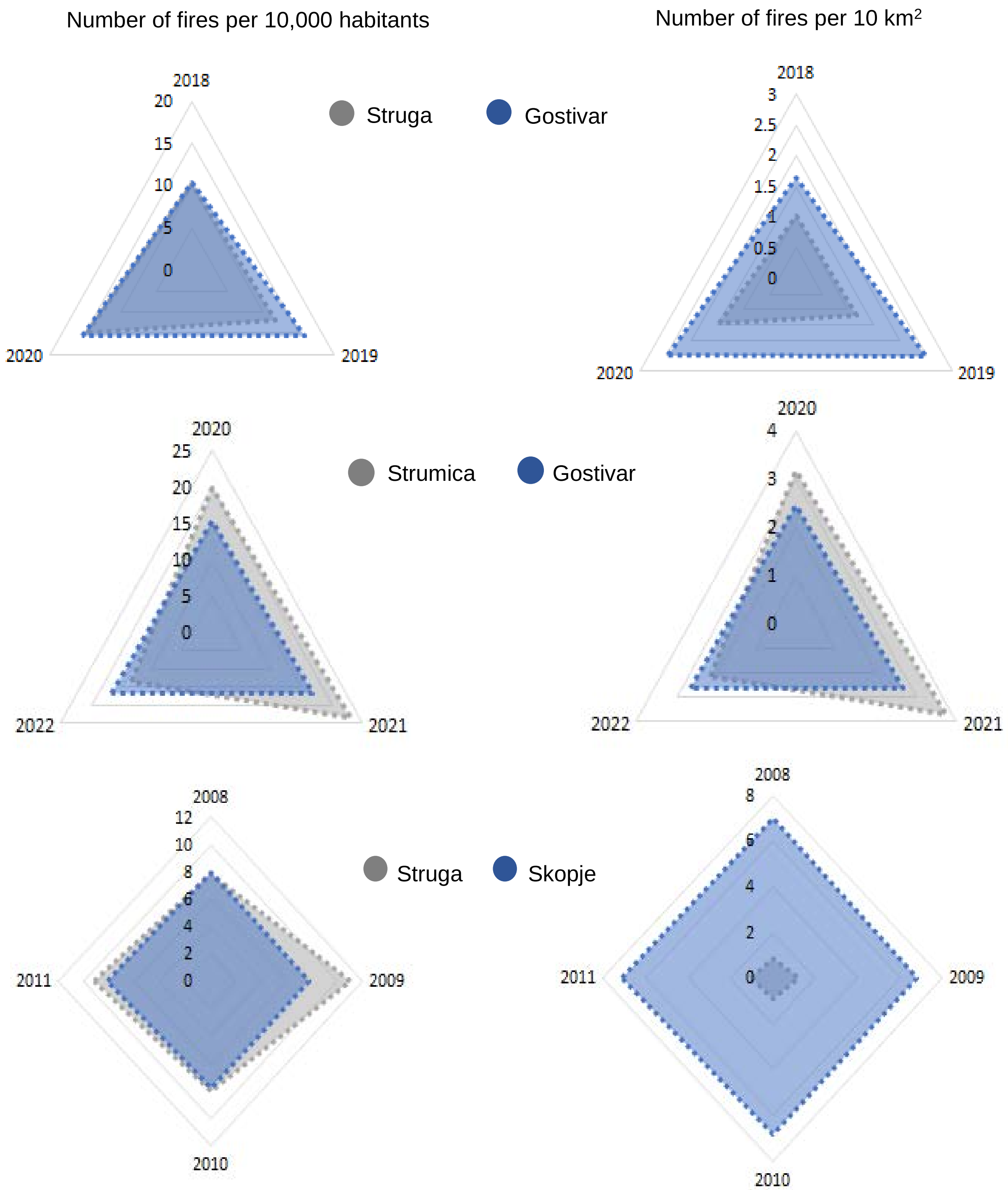

Fig. 5. Comparison of number of fires per 10,000 inhabitants and per 10 km² built-up residential area, for the 4 municipalities for which there is a matching year

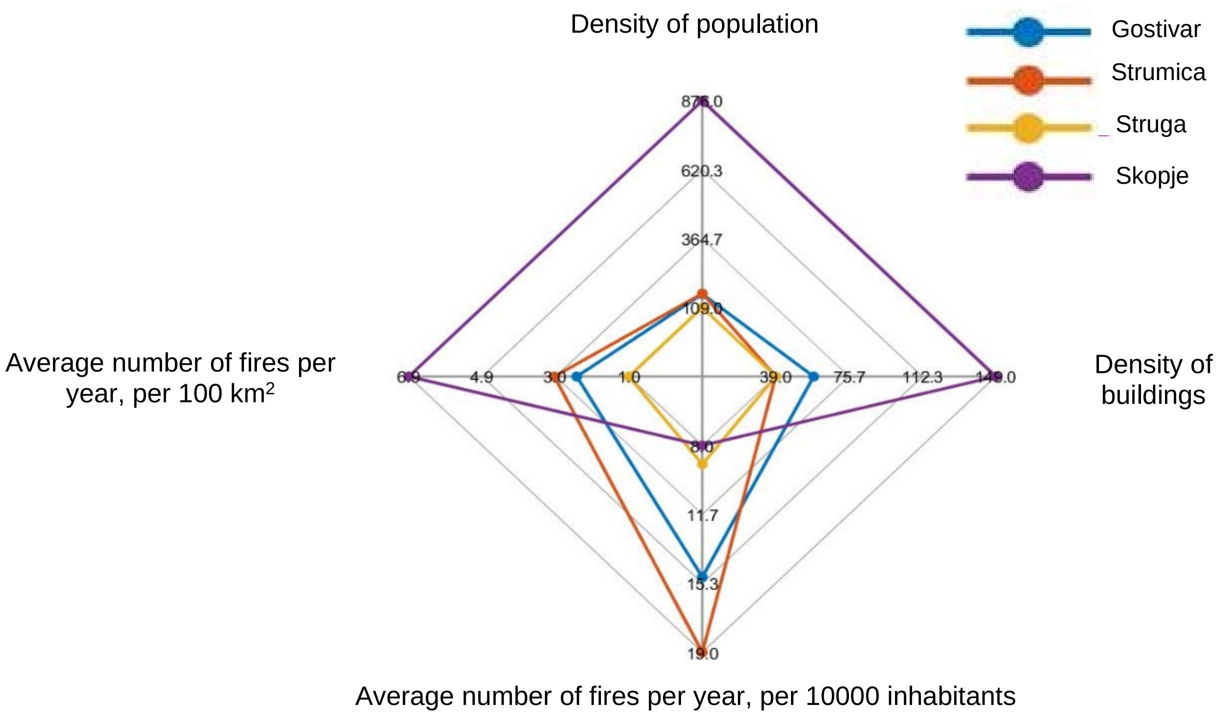

Fig. 6. Comparison of the average number of fires in buildings in one year in the three municipalities and the city of Skopje, per 10,000 inhabitants and per 100 km^2

4 CONCLUSIONS

The interplay between population density and build-up density plays a pivotal role in shaping the level of fire risk within urban areas. Skopje, characterized by its dense built-up environment, stands out with the highest incidence of fires when compared to neighboring cities such as Struga, Gostivar, and Strumica. The concentrated clustering of structures and inhabitants in Skopje amplifies the likelihood and intensity of fire incidents, underscoring the critical importance of managing urban density to mitigate fire hazards effectively.

Further research should take into account the following:

- In order to define the vulnerability of buildings, data on the type, height and age of the buildings are needed, both by municipality and by quarter, as well as statistical data on fires that have occurred in such categorized buildings, but these data do not exist in North Macedonia.
- In order to define the vulnerability of users of buildings (residents or employees), it is necessary to categorize the population by municipality and neighborhood (age, possible disability, etc.), as well as statistical data on fire victims by population category, but the corresponding data do not exist.
- The distance of the buildings from the FF brigades, their location in relation to the access roads and the existing fire-fighting equipment are additional factors that affect the vulnerability of both the buildings and the tenants. Appropriate data can be obtained by looking at urban plans and surveying tenants, but the format of the data would depend on the adopted methodology for fire risk analysis in buildings.

Observing and understanding the behavior of buildings in fire, in space and time, gives the opportunity to target measures for improving fire protection for buildings for which the analysis determines that they are characterized by a high risk of fire.

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