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Anna Maria Kowalczyk[1], Tomasz Bajerowski[2], Michał Ogrodniczak[3]

A Method for Hazard Mapping Illustrated with an Example of Fire Service Interventions

Abstract: Spatial information systems are already widely used and are commonly applied in crisis management. The aim of the study was to develop a method for mapping hazards as a tool supporting crisis management processes and decision-making processes for the purposes of security and activities of the Fire Service, and the organisation of the National Rescue and Fire System. As part of the study, formulas determining the scale of danger of each event, and a danger scale factor were developed. Hazard maps were compiled using various methods of cartographic presentation, including interpolation, chorogram, and hotspot. The data used was information from the National Fire Service, from an area accepted as representative. The suggested solution proposes a new method for spatial analysis which takes into account not only the number of events as such, but also the weight of hazards they generate, the specified scale of dangers. The conducted study indicates that the hazard map compiled using this method show more spatial relationships than raw statistical data, which enables a better analysis of the studied phenomenon. The end result of the study is the development of algorithms enabling the compilation of a hazard map which takes into account not only the very fact of the occurrence of a hazard but also its weight.

Keywords: hazard map, analysis, geo-information, the Fire Service, GIS, interpolation

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[1] University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Geodesy and Building Engineering, Department of Geodesy, Olsztyn, Poland, email: anna.kowalczyk@uwm.edu.pl
ORCID ID: https://orcid.org/0000-0002-4580-7479

[2] University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Geodesy and Building Engineering, Department of Geoinformation and Cartography, Olsztyn, Poland, email: tbajer@uwm.edu.pl
ORCID ID: https://orcid.org/0000-0003-2808-0164

[3] University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Geodesy and Building Engineering, Department of Geoinformation and Cartography, Olsztyn, Poland, email: michal.ogrodniczak@wp.pl
ORCID ID: https://orcid.org/0000-0001-7207-877X

1. Introduction

Spatial data are data referring to objects, events, or processes, which can be presented in the adopted coordinate system [1–4]. Geo-information (spatial) analysis is a process of studying spatial data, aimed at obtaining new, reliable spatial information on their basis in order to solve a problem situation, and to provide an answer to a question asked about an object, event, or process. Spatial analysis enables the modelling of complex events, relationships, and geographical processes, and is used for monitoring and forecasting. Geo-information analysis is used in numerous fields of research into spatial security. Modelling of the Fire Service interventions is a complex process [5–10].

The basic parameters describing each crisis situation or hazard include the location and time. Therefore, a map as a model showing the contents in relation to the space, which are of interest to us, to a scale convenient to us, provides the basis for geo-information analyses.

The authors of the article define a hazard map, a type of thematic map from the group of socio-economic maps. It is a graphical and codified model of reality. On this map, the configuration of marks reflects the relationships between the location of a specific hazard, or of additionally estimated value of this hazard, and the location of the components of the modelled reality (geo-spatial features) in relation to the Earth's surface. It can therefore be concluded that the map provides information on the location of a specific hazard or hazards, or, additionally, information on the estimated value of that hazard (the so-called hazard degree) in relation to the analysed geographical space. To determine the location of a hazard or its degree, geo-spatial analysis methods are employed.

Hazard maps serve informative functions for the purposes of planning and the aims associated with decision-taking in many areas of life. The map image can also generate information on the areas affected by a specific hazard, or areas exposed to the emergence of that hazard. These maps also provide information on risks to life or associated with the stay in a particular area. A hazard map can present a single type of a hazard, or several of them in order to obtain a complex picture of natural or civilization hazards. A hazard map can be enriched with additional contents e.g. evacuation routes. The map, similarly to other maps, can be in an analogue or digital form. A digital hazard map is the depiction of spatial data and/or information as a digital image recorded on any data carrier in the form of a file (a database, or a relative database) suitable for display on multimedia devices [6: 5–96, 11–13].

A correctly compiled hazard map provides a possibility for the development of efficient, effective, and economical plans used in Fire Service operations, and is an indispensable component of the security system. Hazard maps provide the basis for the system, and enable proper (optimal and actual) identification of hazards as well as the appropriate targeting of measures.

Hazard maps are compiled with account only taken of the number of events, which results in each intervention being regarded identically in terms of the hazard scale. The conducted study extends these possibilities, and the final result is a new methodology of the compilation of a hazard map in the light of the definition provided.

2. Spatial Data Characteristics

For the purposes of the study, a test area was selected whose features are universal, irrespective of the scope of the spatial study. The area is located in Poland, in the north-eastern part of Kujawsko-Pomorskie voivodeship (Fig. 1), a territorial unit including the Brodnica district. According to statistical data (from Poland's Central Statistical Office, GUS, 2014), its population amounts to 78,431, which, with the area of 1039 km², translates into a density of 75 people per km² [14].

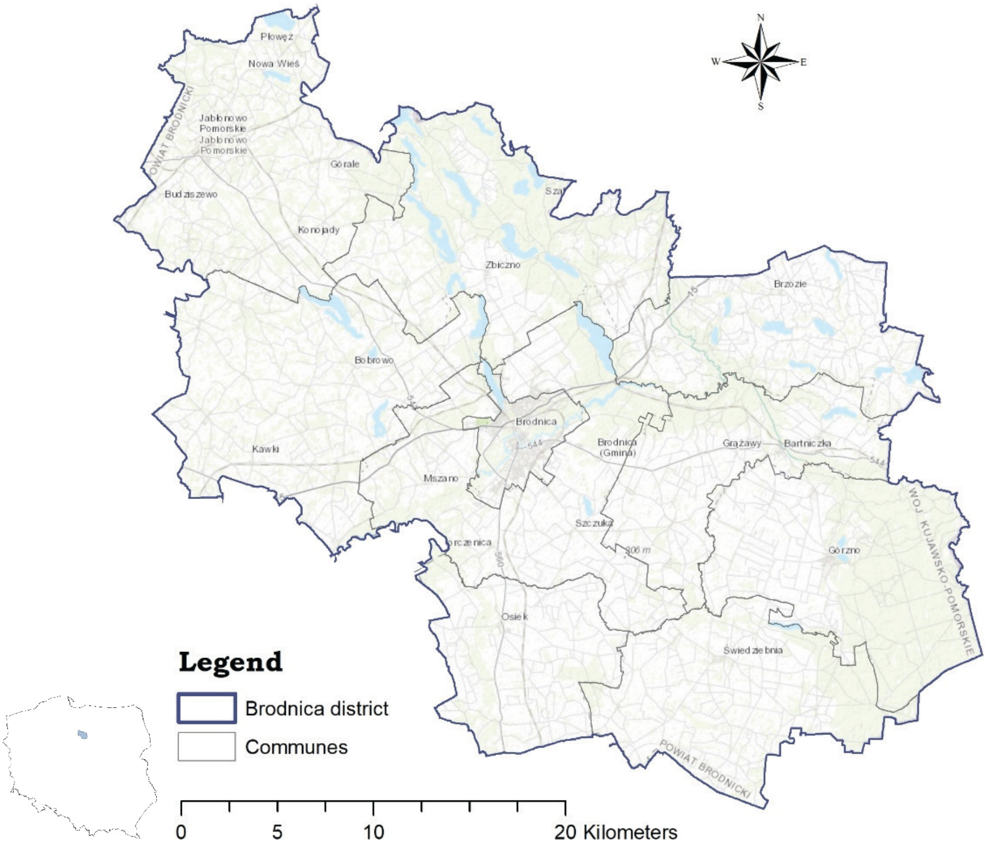

Fig. 1. Location of the test area in Poland.
Administrative division of Brodnica district into ten communes (administrative sub-areas)

Source: own analysis using ArcGIS software

The study used basic fields of assessment in accordance with the administrative division of Brodnica district. Each field was an area within the boundaries of one commune (an administrative sub-area). Fields of this type are mostly used for carrying out studies based on statistical information obtained in the data of administrative units [7, 11, 15].

The data were provided by the National District Fire Service (PPSP) in Brodnica in tabular form. The data are collected in notification sheets. A notification sheet is a document which includes a description of an event, including event type and location, the degree of a hazard and the forecast of its development, the notifier's personal data, the date and time of the notification acceptance, the number and condition of casualties, and any information on the rescuers who arrived at the site of the event. The sheet is an annex to the Regulation on the detailed rules for the organisation of the National Rescue and Fire System [16]. The collected data are characterised by the lack of homogeneity of records and quality. This provides a contribution to work on the use of available data and the need for their unification and assessment.

The analysed data include data on rescue interventions as regards events from the years 2014 and 2015. Each intervention involving the Fire Service was assigned attributes. These attributes include the geolocation provided in the form of geographic coordinates, the number of engine companies involved in the intervention, the precise date of notification acceptance with account taken of the time and type of intervention. The data provided by the PPSP in Brodnica reveals that in the years 2014 and 2015, a total of 1,543 interventions were made; however, the number of interventions in 2015 was higher than that in the preceding year and amounted to 853 interventions, while in 2014, there were 690 interventions. The PPSP divided the interventions into the following categories[4]: fires, strong winds, chemical, environmental, collapses, on water bodies, road, municipal infrastructure, medical, and other. This division results from the conclusions of the document issued by the National Headquarters of The National Fire Service (Komenda Główna Państwowej Straży Pożarnej, KGPSP), called "The rules for recording events under the decision-making support system of the National Fire Service" [17: 5–28]. Short characteristics of events are presented in the "Methodology" section of this article. The number of interventions within a particular category is presented in Figure 2.

According to the information presented in Figure 2, the Fire Service made the most interventions in relation to the events of the "Fires" category. The second group includes the interventions described as "Other", as the nature of these interventions prevented them from being included in the remaining categories. In this group, the most frequently recorded events primarily included police assistance which involved allowing the entering into a building during an intervention. The least recorded interventions were those of "Environmental" category: there were

[4] The rules for recording events under the decision-making support system of the National Fire Service

only two in 2014. Events of the "Road" or "Strong Winds" categories were recorded just as frequently. Most interventions took place in the municipality of Brodnica, a central part of the district. A total of 745 interventions were made there.

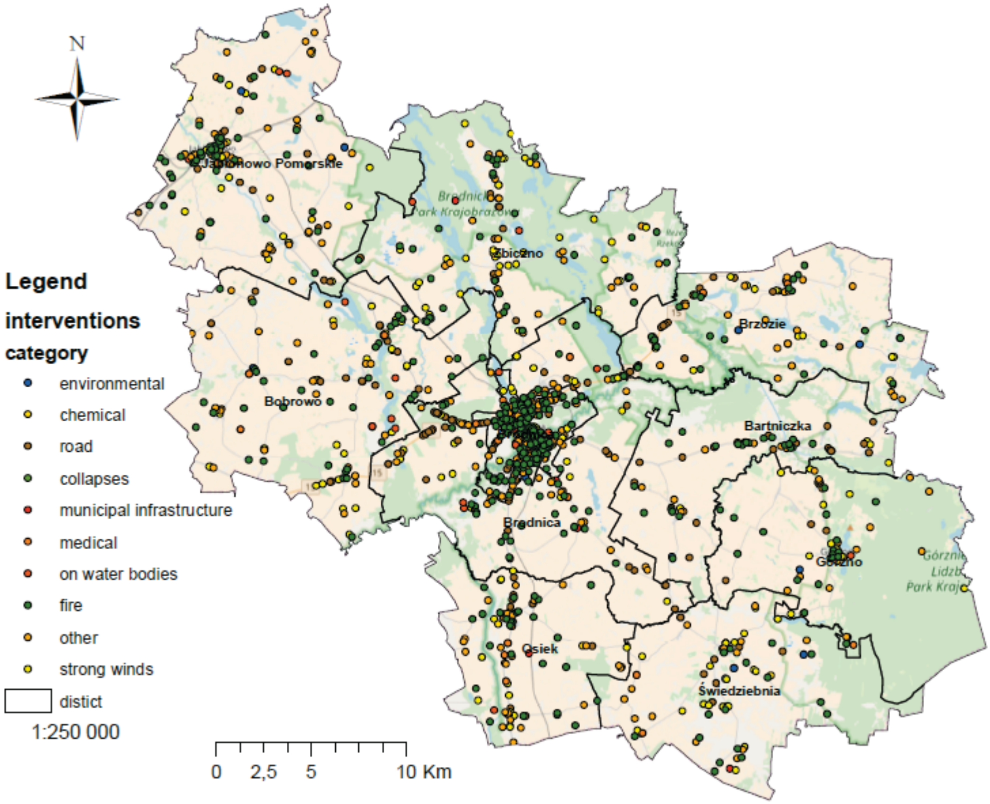

Fig. 2. Number of interventions in the years 2014–2015, broken down into particular event categories

Source: own analysis based on the data obtained from PPSP Brodnica

The data provided by PPSP Brodnica also enable the characterisation of interventions in terms of the time of year in which they were made. In various seasons, the space is characterised by different features which can generate certain hazards.

An analysis of the above-mentioned graph reveals that most interventions involving the Fire Service were recorded during the summer holiday months i.e. July and August. However, the number of interventions (254) in July is significantly higher. In other months, this number is approximate with a slightly higher number of interventions in January and March. The average number of interventions excluding extreme values (interventions in July and August) amounts to 106 interventions per month. This spatial analysis shows the correlation between the events and the time during the year. It provides a basis for taking measures preventing the occurrence of hazards such as the elimination, adding, modification, or change to the spatial position and the configuration of spatial features contributing to the generation of a hazard.

The form of the data provided also enable a thorough time analysis as regards the time of an event. The time assigned to a particular event denotes the time of acceptance of a notification of the particular incident. Firefighters accepted the most notifications in the evening hours, particularly from 7:00 PM to 9:00 PM, and in the afternoon, at 4:00 PM. The graph clearly shows the difference between the number of notifications accepted during the daytime and those notified at night. From 10:00 PM to 06:00 AM, light colours are dominant in the graph as the number of notifications on this time of day is significantly smaller. In a numerical ratio, at night, 118 notifications were noted in the years 2014–2015, while during the daytime as many as 1,298, which is practically six times more than the number of night notifications. The conducted analysis reveals at what times during the day most events occur. This enables the planning of rescue unit operations in terms of transport accessibility, logistics, and the proper amount of forces and resources in a particular area.

The factor which enables, to a large extent, the determination of the scale of a particular event is the number of engine companies which were involved in an intervention. Most interventions involved 1 Fire Service engine company. An engine company is a subunit of three to six rescuers, including the commander, equipped with a vehicle adapted to the performance of a rescue task [16]. One intervention was recorded which required the participation of as many as 11 engine companies. This particular intervention concerned the extinguishing of a woodworking shop fire. Events involving a greater number of engine companies are mainly fires, while interventions involving a single engine company are related to events of the "Strong Winds" category. In road accidents, an average of two to three Fire Station engine units participated. Interventions involving four or five engine companies were primarily related to events on water bodies.

3. Methodology

The study used data on events from the years 2014–2015, provided by the National District Fire Service in Brodnica, and described in the previous chapter. GIS software, namely ArcGIS, was uses as a tool for the development of a database, for the cartographic presentation of an event, and for further geo-information analyses. The obtained data were assessed for completeness and quality, and unified to the form of a database.

Numerous hazard maps are developed while taking into account only the number of events, which results in each intervention being treated equally in terms of the hazard scale. Consequently, these models do not show the issue in an optimum manner, as e.g. a road event involving casualties is not equal to an event of the “Other” category, e.g. unlocking a flat. Therefore, it was decided during the study that an additional factor i.e. the scale of the danger posed by a particular event should be taken into account. To this end, a formula was developed to determine such a scale for a particular event. This formula uses the attributes assigned to events and transforms them into factors. However, in order to impart weight, a two-point scale was assigned to each factor. The scale of a hazard was calculated as the arithmetic mean of all factors characterising the event.

The determination of the scale of the danger may be described by a general formula:

$$Sk = \frac{(c1 + c2 + c3 + \ldots + cn)}{n} \tag{1}$$

where:

Sk – the scale of the danger,
$c1$ – first factor,
$c2$ – second factor,
$c3$ – third factor,
cn – the last factor,
n – number of factors.

The number of factors can take values from 1 to n factors, depending on the prescribed attributes. The number of factors can also be modified depending on the number of attributes assigned to the events. After a detailed analysis of event in particular categories it was demonstrated that each event of a particular category has three common factors (Tab. 1), while the fourth factor is specific for a particular category. Then, it determines the need for modification of Formula (1), and the scale of a danger will be determined according to the following formula:

$$Sk = \frac{(c1 + c2 + c3 + \ldots + cn)}{4} \tag{2}$$

where:

Sk – the scale of the danger,
$c1$ – first factor,
$c2$ – second factor,
$c3$ – third factor,
$c4$ – fourth factor.

The description of common factors included in Formula (2), along with their scale, is provided in Table 1.

Table 1. The description of factors along with the scale of the danger

Factor name		Scale	Description of the scale
*c*1	The time of the day in which the event occurred	1	Day (an event occurring from 6 AM to 10 PM)
		2	Night (an event occurring from 22 AM to 6 PM)
*c*2	Event type	1	Minor [18]
		2	Local, medium (major in case of fires) [18]
*c*3	Number of engine companies involved in an intervention	1	1 or 2 engine companies
		2	More than 2 engine companies

The fourth factor relates to the event type, which are divided into:

– fires, defined as an uncontrolled combustion process in a location which is not intended for such processes;
– local hazards which are divided into minor, local, medium, major, or giant ones, and natural disasters.

These include: strong winds, water rises, snowfalls, rainfalls, municipal infrastructure, chemical, environmental, radiological, collapses, medical, transport: road, rail, and air, and hazards on water bodies. A detailed description of the parameters for classifying local hazards into a particular group, and the characteristics of hazards are provided in "KGPSP" [17: 5–28]. Description of the fourth factor for a particular category, applied in Formula (2), is presented in Table 2.

Table 2. Description of the fourth factor "c4" for particular categories of events which took place in the test area in the years 2014–2015

Event category	Scale (in points)	Description
Fire	1	**Minor** – "A fire is minor when it results in the following either burnt or destroyed: (a) structures or their parts, movable properties, storage facilities, machinery, equipment, raw materials, fuels, etc., with an area of up to 70 m^2, or a volume of up to 350 m^3; (b) forests, crops, grasslands, peat bogs, and wastelands, with an area of no more than 1 ha". **Medium** – "A fire is medium when it results in the following either burnt or destroyed: (a) structures or their parts, movable properties, storage facilities, machinery, equipment, raw materials, fuels, etc., with an area from 71 to 300 m^2, or a volume from 351 to 1500 m^3; (b) forests, crops, grasslands, peat bogs, and wastelands, with an area of more than 1 ha and no more than 10 ha". Fires which posed no threat to human lives and health, and only resulted in material losses
	2	**Major** – "A fire is major when it results in the following either burnt or destroyed: (a) structures or their parts, movable properties, storage facilities, machinery, equipment, raw materials, fuels, etc., with an area from 301 to 1000 m^2, or a volume from 1501 to 5000 m^3; (b) forests, crops, grasslands, peat bogs, and wastelands, with an area of more than 10 ha and no more than 100 ha". **Giant** – "A fire is severe when it results in either burnt or destroyed areas or volumes which exceed the values provided for a major fire". Fires posing greater hazards to lives, health, and possessions than fires of the "Major" and "Medium" categories; vehicle fires

Table 2 cont.

Strong winds	1	Events resulting from the occurrence of strong winds, tornadoes, hurricanes, and storms, e.g. damaged roofs and other parts of buildings. They pose no hazard to human health and lives, and do not result in damaged possessions, e.g. fallen trees or broken branches outside a built-up area
	2	Events resulting from the occurrence of strong winds, tornadoes, hurricanes, and storms, e.g. damaged roofs and other parts of buildings. The pose a hazard to human health and lives, and result in damaged possessions, e.g. a tree fallen on a power line, a tree bent over a building or a road, or damage to a building due to a strong wind
Chem-ical	1	Events resulting from a release of hazardous substance to the environment, which pose a danger to lives, possessions, or the environment. No casualties. A small to medium area of contamination
	2	Events resulting from a release of hazardous substance to the environment, which pose a danger to lives, possessions, or the environment. Casualties. A large to very large area of contamination
Envi-ron-mental	1	Events resulting from human activities or natural forces, which pose a hazard to the environment (the air, water, soil), e.g. an oil slick on water, unsealing of a fuel tank. Restoration of the state of environment to the condition before the event is performed using specialist equipment as well as measures affecting the elements of the environment. No casualties. A small to medium area of hazard
	2	Events resulting from human activities or natural forces, which pose a hazard to the environment (the air, water, soil), e.g. an oil slick on water, unsealing of a fuel tank. Restoration of the state of environment to the condition before the event is performed using specialist equipment as well as measures affecting the elements of the environment. Casualties. A large to very large area of hazard
Col-lapses	1	Events resulting from the destruction of or damage to a built feature either under construction or an existing one, its parts or particular elements e.g. minor damages to a building, for example damaged rain gutter, blown off roof elements. No casualties
	2	Events resulting from the destruction of or damage to a built feature either under construction or an existing one, its parts or particular elements e.g. more serious damages to a building, for example roof collapse, and damages which may pose a hazard to health and lives of the people staying in the building. Casualties
On water bodies	1	Related to events on watercourses and natural or artificial water bodies, and being no water rises; events on small rivers and watercourses
	2	Related to events on watercourses and natural or artificial water bodies, and being no water rises; events on rivers and lakes
Road	1	Destruction of, damage to, or collisions of road transport vehicles during their movement or stop, occurring on road traffic routes or car parks, whose results pose a hazard to lives, health, or possessions; minor and local
	2	Destruction of, damage to, or collisions of road transport vehicles during their movement or stop, occurring on road traffic routes or car parks, whose results pose a hazard to lives, health, or possessions; medium, major, severe, or a natural disaster

Table 2 cont.

Event category	Scale (in points)	Description
Municipal infrastructure	1	Events resulting from damage to or destruction of equipment and systems, in particular gas fittings, plumbing installations, heating, energy, and lift systems, etc., preventing their standard operation; minor and local; events involving e.g. pumping out water from a residential building
	2	Events resulting from damage to or events resulting from damage to or destruction of equipment and systems, in particular gas fittings, plumbing installations, heating, energy, and lift systems, etc., preventing their standard operation; medium, major, severe, or a natural disaster; events involving e.g. gas main failure, damaged wire
Medical	1	Events resulting in a state of an acute health hazard, requiring that casualties be given qualified first aid by Fire Protection Unit rescuers; minor and local
	2	Events resulting in a state of an acute health hazard, requiring that casualties be given qualified first aid by Fire Protection Unit rescuers; medium, major, severe, or a natural disaster
Other	1	Given that events involving the Fire Service, which posed negligible hazards to health and lives, were included in the "Other" category, all events of this category were assigned a value of only 1 point. In these events, no more than one Fire Service unit participated

Source: own analysis based on [17: 5–28] and data from PPSP Brodnica

The mean value calculated according to Formula (2) does not reflect the impact of particular events on the danger scale for the basic field set. Therefore, the authors developed a formula to determine a danger scale factor for particular basic fields of assessment. This factor was used to develop a generalised hazard map. A formula for the danger scale factor for a basic field was written down in a general form:

$$WSk = \frac{(Sk1 + Sk2 + Sk3 + \ldots + Skn)}{Lz} \tag{3}$$

where:

WSk – scale of the danger factor for a basic field,
$Sk1$ – scale of the danger for the first event,
$Sk2$ – scale of the danger for the second event,
$Sk3$ – scale of the danger for the third event,
Skn – scale of the danger for the n-th event,
Lz – number of events in a basic field.

4. Cartographic Visualization of Hazards in Accordance with the Developed Method

Cartographic methods of data presentation can be divided into qualitative and quantitative methods. The qualitative methods include signature method, chorochromatic method, and method of ranges. The quantitative methods include dot method, chorogram method, isoline method, and diagram method [2, 19–21]. Moreover, GIS software enables the performance of simple spatial analyses whose results are presented in the form of a map. An example of a map compiled using analytical tools is a density map (Fig. 3). Various combinations of the presentation form can be applied, provided that they are in line with the logic of the map and the presented contents [21–24].

All these methods can be employed to compile a hazard map. However, depending on the type of a hazard or a group of hazards under analysis, an appropriate method needs to be selected. The proper selection of a cartographic presentation method enables the proper interpretation of the analysed phenomenon, and thus obtaining useful information in order to take decisions and plan operations. Below, the authors present various methods of cartographic presentation of data on events in terms of compiling hazard maps with account taken of the developed algorithms as an additional factor providing better quality of the information read from the map [3, 8, 25, 26].

In order to present the results of the developed method in a visual form, ArcGIS software was used. To develop an optimum manner of cartographic presentation of this issue, various mapping methods were used as well as data on events, both those relating to the location itself and those taking the scale of the danger (*Sk*) and the scale factor (*WSk*) into account. A model using GIS environment is a map of the density of events based on the data on the location of event occurrence (Fig. 3). This map does not take into account the scale of the danger for particular events.

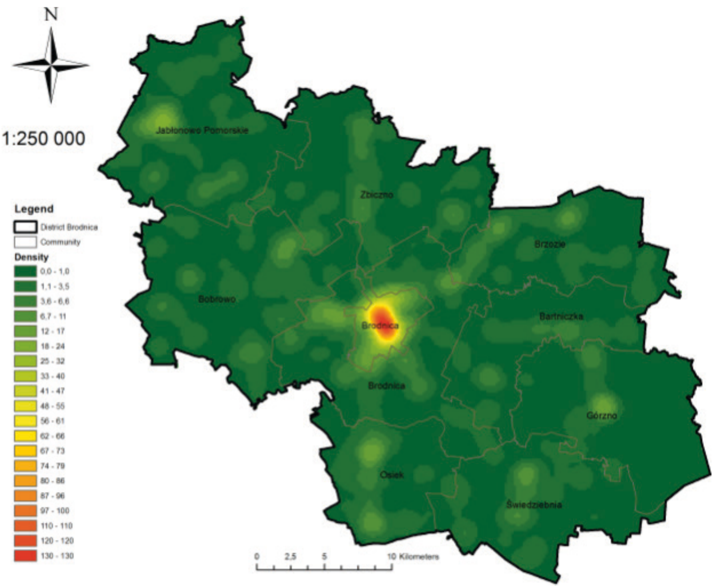

Fig. 3. Map of the density of events to which interventions of the Fire Service were directed in the years 2014–2015 in the test area

It can be noticed that the map perfectly shows where most events occurred, and thus where most interventions were made. However, it treats all events equally in terms of the hazard scale, and it is not possible to determine locations with the greatest number of dangerous events on its basis. The map only indicates their total number.

The next map is an isoline map (Fig. 4). The data used for the compilation of this map was the information on the scale of danger for a particular event (*Sk*), calculated from Formula (2). The applied interpolation method is the IDW (Inverse Distance Weighting). The method was selected due to its advantage of highlighting the extremes [27, 28].

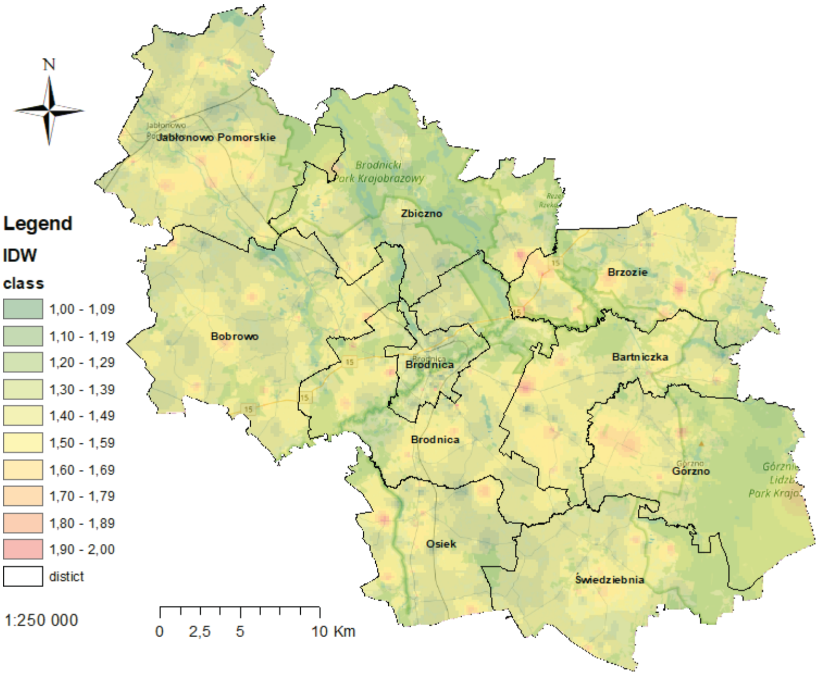

Fig. 4. A hazard map using the IDW for all events

The interpolation method enabled the compilation of a hazard map which shows the spatial reference of hazards, including the scale of the danger for a particular hazard. However, the method should be applied cautiously in case of events of such type. This results from the fact that events are not of continuous nature, and looking for medium values between two events may lead to improper modelling of the issue, and thus to wrong conclusions. Nevertheless, the locations where events occurred more frequently can be seen clearly in the map. It identifies the spaces which generate a greater hazard, while taking the scale of the danger of events into account (Fig. 4). Therefore, it can be concluded that the features which generate these hazards accumulate in these spaces, and that these features need to be removed or modified in order to reduce a hazard or add new spatial features to increase security (e.g. monitoring). Moreover, the forces and resources of rescue structures must also be planned in accordance with the trend for the development of the phenomenon: equipment, rescuers' training, etc.

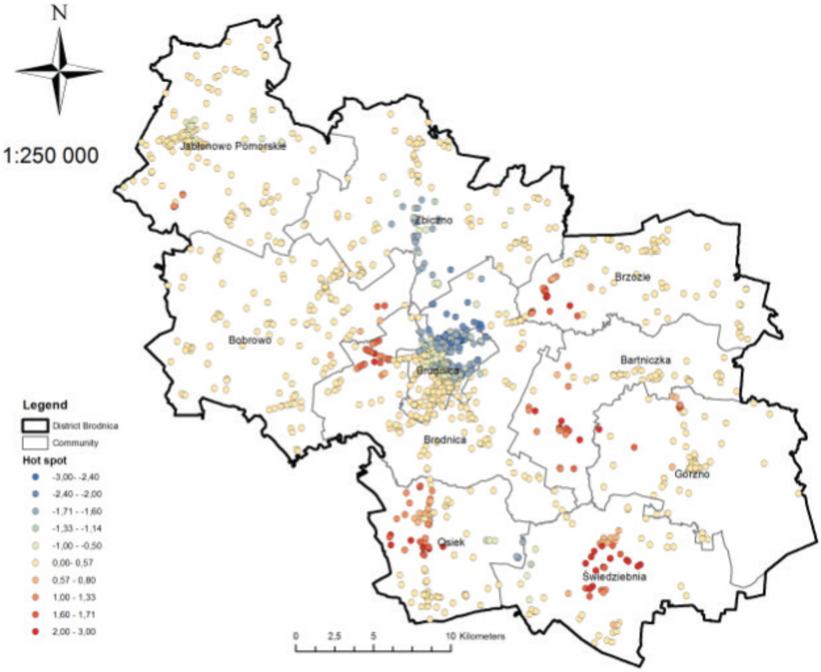

Fig. 5. Hot Spot map of hazards

Another map shows the distribution of events along with the scale of the danger for particular hazards, using the signature method (Fig. 5) [21]. In this case, signatures are marks (circles) plotted on the map with a point reference, with geographic location determined using coordinates. This method also applies color scaling i.e. uses colors to present the scale of the danger for a particular event. The Hot Spot tool enables the depiction of "cold" and "hot" points on the map in the spatial context, with the scale of the danger taken into account. The more a point's color is similar to red, the greater scale of the danger was posed by the event; the more a point's color is similar to blue, the smaller the scale was.

The model presented in Figure 5 shows specific points in the space, in which the events took place, along with colour designation of the scale of the danger posed by the event, calculated from Formula (2). This map enabled the identification of locations in which the most dangerous events occurred more frequently. Not only does it show the spatial location but also the degree of danger for a particular event. In the test area, it enabled the identification of areas into which measures preventing the generation of a hazard must be introduced. An important element in the presentation of issues in the cartographic form is the process of generalisation i.e. reduction in the detail level of the map. A more generalised map provides us with more general information. In order to compile such a map, a scale of the danger factor was calculated for each basic field using Formula (3). The result of cartographic presentation applying the chorogram method is shown in Figure 6.

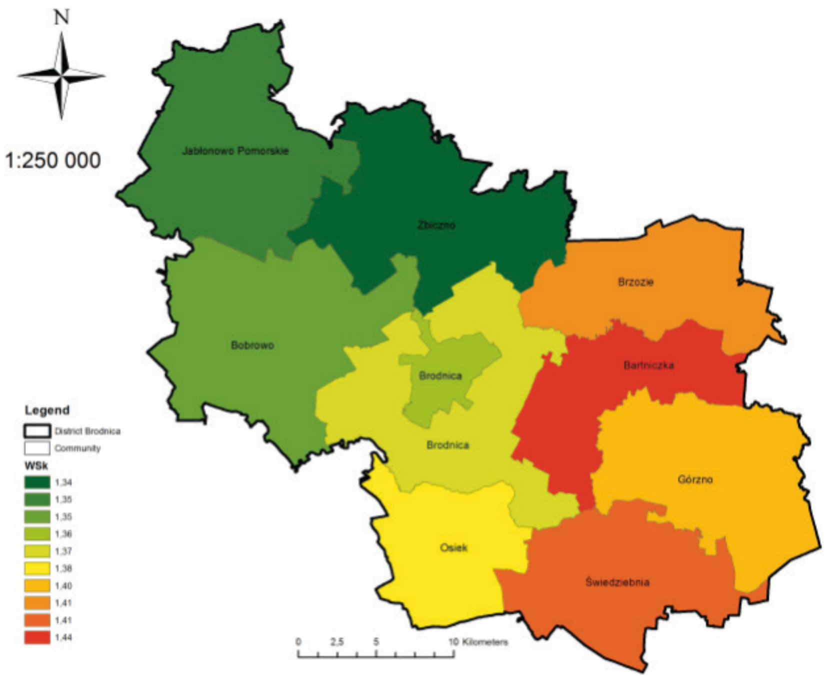

Fig. 6. A chorogram of the factor of the scale of hazards to which the Fire Service interventions were directed, for particular basic fields of assessment

The map presented in Figure 6 presents, in a general manner, quantitative information on hazards, with the scale of hazards taken into account. In the above case, the hazard scale factor, calculated for particular communes (basic fields), did not take into account the number of events which had occurred. It determined the arithmetic mean from the scale of the hazard *Sk* for a particular field (2). Undoubtedly, the number of events is a significant factor which should be taken into account. Therefore, it was proposed that weight should be assigned while calculating the *WSk* factor (3), and new, weighted hazard scale factors WSk_L were calculated:

$$WSk_L = P_i \cdot WSk_i \tag{4}$$

$$P_i = \frac{z_i}{M} \tag{5}$$

where:

z_i – total number of events in a commune,
M – total number of events in a district $M = \sum_i^n z_i$,
n – number of communes/municipalities in a district,
$i = 1, 2, 3, ..., n$.

A generalised hazard map for particular basic fields following the introduction of modifications is presented in Figure 7.

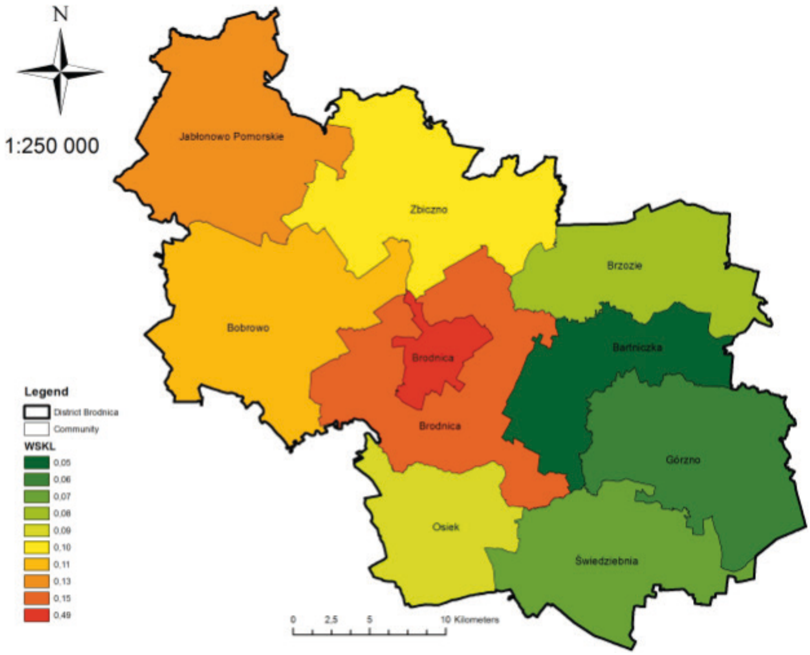

Fig. 7. Chorograms of the weighted factor of the scale of hazardous events to which the Fire Service interventions were directed, for particular basic fields of assessments (*communes*)

Having taken the number of hazards into account, the map using the chorogram method presents the analysed phenomenon differently. The applied modification resulted in a more reliable model which enables better information on hazards to be obtained. It allows one to determine in which basic field the most dangerous events occurred, and thus, which field generates the greatest hazard and requires most preventive measures as well as the optimisation of measures associated with providing assistance. This is also related to the further process of inference in strategic terms, e.g. economic ones.

Digital cartographic documents using thematic layers enable the plotting of selected contents in order to optimise the inference process. These can be contents concerning spatial data, and those being result of geo-information analyses, e.g. network analyses [12, 18, 29, 30]. A hazard map which shows chorograms for the weighted hazard scale factor, hot spots, and the network of roads in the analysed area, is presented below (Fig. 8).

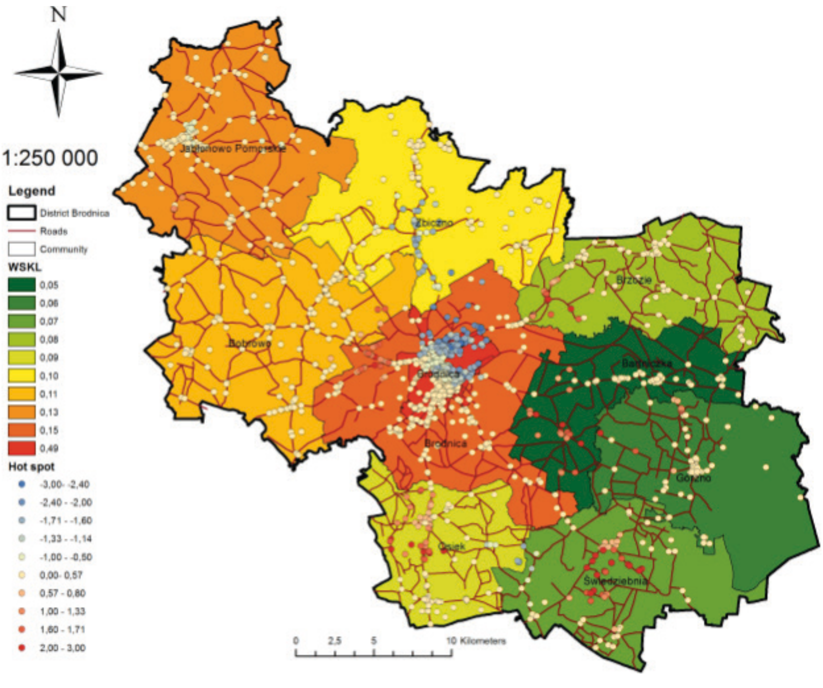

Fig. 8. A hazard map which shows chorograms for the weighted hazard scale factor, hot spots, and the network of roads in the analysed area

5. Summary and Conclusions

The progressing development of spatial structures, resulting in the emergence of new, frequently different types of hazards, requires more and more analyses to be carried out. An analysis of the Fire Service interventions in the test area, according to the method developed in the article, enabled the mapping of hazards, and the determination of dangerous areas. Dangerous areas are defined as events requiring an intervention of the Fire Service.

During the performance of spatial analysis, the categorisation of data is important. This categorisation often involves certain description of data by assigning a scale of importance to them. The method enables the compilation of maps of hazards and interventions of the National District Fire Service, with the scale of hazards i.e. the weight of a particular hazard taken into account. Prior to the development of the method, it was assumed that not all events were equal i.e. one event results in more adverse effects than another; therefore, it was necessary to introduce the scale of the danger for particular events. Based on the data calculated using innovative algorithms, hazard maps were compiled using various methods for the visualisation of data and spatial information. An event density map, a hazard map using the IDW, a Hot Spot map of hazards, chorograms of the hazard scale factor, and chorograms of the weighted hazard scale factor. The study also developed a map using combined methods for spatial data presentation, i.e. a hazard map which shows chorograms for the weighted hazard scale factor, hot spots, and the network of roads in the analysed area. The thus compiled hazard maps provide more realistic results. The method was based, in its entirety, on the use of spatial data. A great possibility for the use of GIS tools was indicated, which would enable the smooth implementation of the method.

The compiled hazard maps provide information on the studied phenomenon in terms of spatial location, the number, and the scale of the danger for a particular event. Such models provide a possibility for the proper interpretation of information in order to draw reliable conclusions. The presented cartographic models enable the rapid and proper identification of the spaces in which events occurred, and thus those which generate a hazard. This provides a possibility for the development of further measures associated with the inventory of the space and its features, whose configuration results in the emergence of hazards. This process should lead to drawing conclusions and planning the measures which should be taken in terms of changes to the spatial configuration of features (design and architectural measures) as well as for the analysis and planning measures and the equipment of the Fire Service rescue units. The developed cartographic documents are a good source for further research associated, *inter alia*, with planning the location of the Fire Service stations. They are also an indispensable element when preparing strategic documents and plans related to the measures taken during the occurrence of dangerous events and in crisis situations such as National Rescue and Fire Systems. The development of any rescue plans is preceded by the performance of analyses, including spatial analyses which must take into account the hazards which have already occurred and those which may occur in the area for which a document is under preparation. To this end, the data concerning geographic location of all elements of interest must be taken into account. The developed method is a proper tool for supporting these processes.

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Metoda mapowania zagrożeń na przykładzie interwencji Straży Pożarnej

Streszczenie: Systemy informacji przestrzennej są obecnie powszechnie wykorzystywane i znajdują szerokie zastosowanie w zarządzaniu kryzysowym jako narzędzie wspierające procesy decyzyjne. Narzędzia geoinformacyjne umożliwiają identyfikację przestrzenną zagrożeń, modelowanie danych przestrzennych, opracowywanie scenariuszy stanów przyszłych zagrożeń oraz opracowywanie planów zapobiegania wystąpienia kryzysu i jego skutków. Mapy zagrożeń są

narzędziem wykorzystywanym do wspierania procesów decyzyjnych w przypadku zagrożenia.
Celem pracy było opracowanie metody, która pozwoli na kartowanie map zagrożeń jako narzędzia wspierającego procesy zarządzania kryzysowego oraz procesy decyzyjne dotyczące bezpieczeństwa i działań zarówno Straży Pożarnej, jak również krajowego systemu ratowniczo-gaśniczego (KSRG). W ramach badań opracowano wzory określające skalę niebezpieczeństwa każdego ze zdarzeń oraz współczynnik skali niebezpieczeństwa. Opracowano mapy zagrożeń z wykorzystaniem różnych metod prezentacji kartograficznej, w tym: interpolacji, kartogramu, hotspot. Jako dane wykorzystano informacje z PSP z obszaru przyjętego jako reprezentatywny. Zebrane dane charakteryzowały się brakiem jednorodności zapisu i zróżnicowaną jakością. Skutkowało to potrzebą ich unifikacji i dodatkowej oceny. Efektem końcowym badań są algorytmy pozwalające na kartowanie map zagrożeń, uwzględniających nie tylko sam fakt wystąpienia zagrożenia, ale również jego wagę oraz skalę niebezpieczeństwa. Wykonane badania wykazują, że opracowane tą metodą mapy zagrożeń obrazują więcej zależności przestrzennych niż surowe dane statystyczne, co pozwala na lepszą analizę badanego zjawiska.

Słowa kluczowe: mapa zagrożeń, analiza, geoinformacja, Straż Pożarna, GIS, interpolacja