Use of geographic information systems in crisis management

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Abstract. Key factor in the crisis management decision-making process is complete, easy-to-use, and quickly available spatial information on protected interests, preparedness, and vulnerability in the area. Technology progression of geographic information systems help us significantly simplify and speed up this process. It helps us to visualize this essential information for the strategic level of crisis management.

1. Introduction
Complete, easy-to-use and quickly available spatial information about the area of interest is very useful in the decision-making process in the field of emergency planning and crisis management. Such information may include data on phenomena distributed in space, on the factors that affect these socially important objects and, of course, their geoinformation location, i.e., location in the territory. Thanks to the development of technologies such as geographic information systems (GIS), this process has been significantly simplified and accelerated. In the Czech Republic, GIS is used in the field of safety planning, especially for information on protected interests, preparedness, and vulnerability of the territory.

GIS can be applied in all phases of emergency planning and crisis management. In the first phase in the analysis of the situation before the decision-making process on the adoption of measures. GIS can play an important role in ensuring emergency preparedness, in preventing or mitigating the consequences of crisis situations, in responding to a crisis situation, and also in rebuilding the affected area. In the phases from preparation to recovery, GIS can serve as an integrating core of the entire comprehensive preparedness, response and recovery system, or as a source of information that can be used in real time on site. During crisis situations, GIS becomes an integral part of the process of assessing the size and extent of damage, reconstruction and public awareness [1].

The data used in emergency planning and crisis management are mainly spatial in nature, as there is a relationship to certain places in the area of interest and can therefore be displayed on a map. These data can then be analyzed, and decision-makers can respond more quickly to a crisis situation. Crisis situations are occurring much more often than ever before, and crisis management personnel face the difficult task of protecting human lives, movable and immovable property, the environment, and social values [2]. The solution of these tasks is facilitated by GIS, thanks to the use of which it is possible to increase the safety of the population before the occurrence of a naturogenic or anthropogenic emergency, during it and after its aftermath.

The above-mentioned GIS possibilities are very important in many areas that concern the safety of the population and the protection of property, but especially in practice for the components of the integrated rescue system. One such area is emergency and crisis planning, where GIS has gradually evolved into a useful tool to support decision-making at all levels of management, i.e., tactical,
operational and strategic. GIS has achieved this role of supporting and managing information mainly, though not exclusively, through its ability to represent certain aspects of crisis situations on the map. Maps in general have long played an important role in emergency and crisis management, long before GIS evolved into what we know today [2].

The geographical context of crisis situations can be thought of in a similar way as when asking the basic aspects of a given event: who, what, where, why and how [4]. First of all, maps can tell us something about the location or area of adverse effects of the crisis situation and its extent - where buildings were destroyed, where roads are still passable for evacuation, where are the areas most prone to floods, where supplies (water, food, medical supplies, etc.) should be located. For many users of emergency and crisis management mapping tools, knowing the location and extent of a disaster is paramount. It is also important to realize that maps can be used for a deeper interpretation of a crisis situation than just stating where everything happened [15]. Maps also allow you to show the dynamics of processes or the development of phenomena in geographical space. They show what is happening and when it is happening [15].

This allows us to ask questions such as:

- What is the extent of the flood?
- How many people are affected by the effects of a given crisis situation?
- What processes take place in the affected area?
- When will the necessary supplies arrive in the affected area from a certain distribution point?
- What resources are available for crisis planning purposes?

To understand how and why a particular tragedy or crisis has developed, some interaction between the map and the user is needed [5]. Modern GIS tools are the key to this interaction, as they allow dynamic work with the map itself and also with the connected data [15]. In GIS, data layers can be turned on, off, layered, or rearranged. All of this helps to better understand how an event unfolded. Basic operations, such as zooming in or out on a map, allow you to quickly and easily explore areas of interest. The interactive and spatial ability of GIS to query data allows quick access to information that would otherwise be difficult to obtain. Maps can be easily transformed from one cartographic view to another in real time, and also easily shared in various formats with other users and other crisis management teams. In many cases, only these GIS capabilities allow for a better understanding of the situation, faster interpretation, and increased decision-making efficiency. GIS technology provides significant opportunities for crisis management managers. It is mainly about access to data in the administration of local self-government authorities, workplaces of public administration institutions and other authorities connected with the safety situation of the territorial unit. These include, and are not limited to, data describing terrain, watercourses, geological conditions, soils, road and rail network, census data, lists of telephone numbers, floodplains, sources of danger, and finally outputs from the project Risk Mapping in the Czech Republic. Risk mapping is the process by which the manifestations of different types of hazards interact with the vulnerability of a territory and with the preparedness in that territory [9].

GIS can help us identify in a short period of time, for example: buildings that fall into the so-called secure zone [18], finding and mapping paths that were still available to the center of the tragedy, identifying buildings (based on specific criteria) that can serve as temporary evacuation centers, or directly for the emergency survival of the population. Every crisis situation also points out the shortcomings of GIS [6]. Thanks to each crisis situation, new ones are emerging in the field of GIS, such as focusing on 3D GIS, which enables navigation in a multi-storey building, which facilitates the work of rescue services when searching for buildings [7].

Most societies are probably aware that emergencies (natural, anthropogenic, etc.) will expand in the future in terms of size, scope, and intensity. Future crises will affect more people in a given geographical context. Given that disasters are essentially spatial in nature, the use of GIS is self-evident. However, there is a challenge to the training and needs of professionals and specialists who have comprehensive and interdisciplinary technological as well as analytical knowledge of GIS, as
well as knowledge of emergency planning and crisis management [15]. As such, GIS has the potential to increase the level of interdisciplinary research focused on emergency planning and crisis management, thanks to the given spatial components and spatial questions that can be answered using GIS [12].

The article points out the possibility of using GIS in crisis management in solving risk assessment in the border areas of the Czech and Slovak Republics within the R-Plan project. Part of the project is the creation of a common tool and crisis preparedness plans.

2. Crisis management and use of GIS

In the Czech Republic, a group of so-called “crisis legislation” is perceived as part of crisis management. Within this concept, the system of management of rescue situations (MRS) in the conditions of the state was completed. The legal environment in the Czech Republic prefers a two-phase concept of the MRS preparation for extraordinary events and resolution of extraordinary events. However, in the area of territorial safety, experts use a four-phase model of the MRS. Within the individual areas of the MRS, it is possible to look at the possibility of using GIS as a possible tool for increasing preparedness for a crisis situation. The following text includes the individual phases of MRS using GIS.

2.1. GIS and crisis preparedness

The subject of interest is the preparation of the area for crisis situations (CS), where a crisis situation is perceived as an emergency, disruption of critical infrastructure or other dangers for which a crisis situation is declared [8]. Training is divided into non-military (civilian) training and military training. In connection with the issue of preparing the territory for crisis situations, the concept of preparedness can be documented. The preparedness of the territory is perceived as a set of measures designed to mitigate the consequences of the crisis situation, which consists of measures to monitor emergencies and subsequent warning of the population, measures to ensure the resilience of the rescue system and measures to stabilize the situation in the territory and create conditions to restore basic functions in the territory.

One tool for visualizing risks on map is risk mapping. Risk mapping is the process by which risks are classified and quantified in relation to a territory. In this mapping, the manifestations of different types of dangers interact with the vulnerability of the area and the preparedness in the area. The basic assumption is that only those types of dangers can be included in the risk mapping, the manifestation of which in the territory can be expressed in some way in a cartographic representation, i.e. on a map. The risk map visualizes the level of expected losses and damages that can be expected in a certain area and allows you to identify the composition and size of the risk for each part of the territory of the analyzed territorial unit. These are cartographic sheets of a defined area (e.g., municipalities, regions, republic), on which different sizes of risk are marked in colour. Different sizes of risk can be expressed in a multi-level colour scale or in another way. The resulting risk map is based on individual maps of danger, vulnerability and preparedness. The procedure for risk mapping is described in the Methodology for Risk Mapping in the Czech Republic (hereinafter referred to as the Methodology) [9].

GIS data are important for the creation of each of the maps. ESRI's product, ArcGIS, was used for data preparation and processing. Tools for the ArcGIS desktop application for processing the risk map (hereinafter referred to as tools) were created [10]. These geoprocessing tools enabling to perform spatial analyzes and calculations according to the Methodology on the basis of available spatial data. The newly developed tools are implemented on the ArcGIS Desktop platform using the Python programming language and the arcpy spatial library. The input for the tools is data meeting the requirements of the Methodology. The tools are able to assess the integrity and consistency of the input data. The tools are general with an emphasis on, for example: the changing environment, the ability to work with any spatial data meeting the standardization conditions according to the Methodology. The result of the tools is a risk map with attribute data representing all characteristics of the area and with data for the presentation of results and colour visualization of the map, which are used mainly in the field of risk analysis in the area within emergency and crisis planning. In
connection with the Methodology and tools, a web application - Web Application for Risk Mapping (hereinafter the Application) was created for members of the Fire and Rescue Service of the Czech Republic and employees of crisis management authorities (municipalities, regions) [11]. The application (so-called thin map client) presents the results of risk mapping analysis using the existing GIS solution of the Fire and Rescue Service of the Czech Republic (TERINOS from the company T-Mapy). The application is a new tool for obtaining a comprehensive overview of the composition and type of risks in a given area [13]. Methodology for risk mapping in the Czech Republic, tools for desktop application ArcGIS for risk map processing and web application for risk mapping were created within the project VH20182021037 Risk mapping in the Czech Republic, project duration 2018 - 2021. The aim of the project was to create software tool for risk mapping in the Czech Republic [20].

2.2. GIS and crisis prevention

As part of crisis prevention, the results of risk mapping using the Application are used. This information from risk maps will be used in the process of emergency and crisis planning, but also for spatial planning. The reason for using risk mapping is to find information for:

- threat analysis for a specific locality (object, area),
- analysis of the demarcated area (e.g., municipality, administrative district of the municipality with extended powers) with identification of places with higher risk, comparison of defined areas (e.g., municipalities) with each other,
- assessment of individual types of dangers and their impacts on the territory, i.e., on the vulnerability or only a certain part of it.

Based on the information obtained from the Application, it is possible to look preventively at certain types of risks that may endanger a certain area. On the basis of the findings, members of the Fire and Rescue Service may use, for example, municipal cards, emergency and crisis plans or for verification and tactical exercises for a certain type of event occurring in the territory.

The use of GIS is also used to visualize inputs obtained from institutions responsible for monitoring climate change, such as drought (INTERSUCHO), the meteorological service (Czech Hydrometeorological Institute), the geological service or Water authorities. These institutions provide the necessary information for the Fire and Rescue Service of the Czech Republic and crisis management authorities as preventive information on warning of a possible crisis situation and mitigating their impact on protected interests. GIS therefore also offers real-time monitoring of phenomena [14]. The created warnings for the population can be disseminated and shared using mass information resources, for example in the form of web map applications.

2.3. GIS and crisis response

GIS is used in this phase in the field of analysis, setting priorities for rescue operations and creating reports. The reports include maps that show, for example, endangered areas, the nearest shelters or the current location of fire protection units and others assisting in rescue work in the field. The reports provide essential information for crisis management authorities in the event of an effective and timely decision in resolving a crisis situation. Further use of GIS as a component at the operational level of management in operational centers of security forces providing information about units in real time, such as the location of the unit closest to the crisis situation using localization thanks to global navigation systems. This will allow the unit closest to the reported event to be sent. This will reduce the impact on protected interests. GIS can be used to assess the safety situation in the area of [15]:

- an initial assessment of the inventory of damages reported by the field team,
- obtaining satellite and aerial images covering the damaged area,
- collection of spatially specified information and images from social media such as Twitter
- organization of intelligence and citizens' reports
proposing a suitable evacuation from the affected area by a crisis situation [2].

The advantage of GIS is a quick update of changes in the area affected by the crisis situation and providing an accurate picture of this situation. The use of GIS is needed in decision-making within the strategic level of crisis management.

2.4. GIS and crisis recovery

The use of GIS is of great importance in restoring the basic needs of the population and the area affected by the crisis. The immediate importance of GIS lies especially in the short-term renewal of the territory, aimed at meeting the basic needs of the population. GIS can provide answers to a number of safety issues [2]:

- drinking water, i.e., the location of the source of drinking water, the distance from the place of contamination [16],
- information on possible transport routes, closures,
- information on the location of evacuation centers to supply basic needs to residents,
- condition of traffic roads, railways, or tunnels (in case of smoky area) [17].

3. Use of GIS in border areas

Crisis preparedness is a continuous and integrated process that results from a range of risk reduction activities and resources. Decision No 1313/2013/EU on the Union Civil Protection Mechanism requires EU Member States to report to the Commission on their crisis risk management activities in order to support the formulation of an EU risk management policy that complements and reinforces their national measures. The aim is also to find a way to assess and manage risks in the border areas of states. The Czech and Slovak Republics are countries that are trying to find a common approach to risk assessment. Currently, there is an effort within the R-PLAN project (hereinafter the Project) to implement the experience from the Threat Analysis for the Czech Republic to the conditions of the Slovak Republic at the national and subsequently at the regional level [3]. The aim of the project is therefore to assess risks with the same tool and to develop a cross-border (regional level) risk management plan. This is to be done by harmonizing the method of identifying risk assessments in order to improve preparedness and preventive approaches to the protection of the population in cross-border regions. The intention is to develop common tools in the field of data and information sharing between cross-border regions of the Czech Republic (3 regions) and SK (3 regions), which will point to the need for forces and resources in the event of a crisis situation of one, other or both countries [3]. The procedure is a summary of extraordinary events, their frequency, and consequences, it can serve as a risk assessment with the first step of identifying dangers (threats) in the Czech Republic and Slovakia. Within the Czech Republic, the list is completed within the Threat Analysis of the Czech Republic (hereinafter referred to as the TACR) [19]. The list of hazards is defined through the Register of dangers (hereinafter the Register) on the basis of defining dangers that are likely to occur in the Czech Republic. This register contains 72 defined dangers. The register has identified 23 types of dangers with the potential for a crisis situation. In Slovakia, 65 threats were defined within the Threat Register. The next step is the application of Threat Analysis to Slovakia conditions. The coefficients defined within the TACR can be applied on the territory of the Slovakia with minor adjustments, e.g. the assessment of economic losses is according to the domestic gross product of the given country or the definition of the number of persons with death per population of the given country. Here is the possibility of applying the methodology of risk mapping with the resulting level of risk and their visualization in maps using Geoinformation systems. As part of the solution, it is necessary to address issues towards:

- use of a single product for data preparation and processing, use of e.g. ESRI, ArcGIS Desktop and the Python programming language for task automation,
- use of the existing modern configurable web GIS, able to provide various types of user needs - TERINOS for cross-border risk assessment.
The resulting maps with assessed risks in the border areas of the Czech Republic and Slovakia lead to improved preparedness and can be the basis for preventive approaches in the field of population protection in cross-border regions. Furthermore, it will be possible to optimize the overview of forces and resources in the event of a crisis situation.

4. Conclusion
In the Czech Republic, GIS is used in the field of safety planning, especially for information on protected interests, preparedness, and vulnerability of the territory. GIS can be applied in all phases of emergency planning and crisis management. In the first phase in the analysis of the situation before the decision-making process on the adoption of measures. GIS can play an important role in ensuring emergency preparedness, preventing or mitigating the consequences of crisis situations. The article focuses more on the process of risk mapping in the territory with a description of the new methodology for risk mapping in the Czech Republic, tools for the desktop application ArcGIS for creating the risk map, and processing the web applications for user to view the risk mapping. GIS plays another role in responding to the crisis, and also in rebuilding the affected area. In the phases from preparation to recovery, GIS can serve as an integrating core of the entire comprehensive system of preparedness, response, and recovery or as a source of information that can be used in real time at a specific location in a crisis situation. During crisis situations, GIS becomes an integral part of the process of assessing the size and extent of damage, reconstruction, and public awareness.

Disaster preparedness is a continuous and integrated process that results from a range of risk reduction activities and resources. The effort in the framework of the Decision on the Union Civil Protection Mechanism No. 1313/201/EU is also to find a way for risk assessment and management in the border areas of states. The countries that are trying to find a common approach to risk assessment are the Czech and Slovak Republics within the R-PLAN project. The aim of the project is to assess risks with the same tool and to develop a cross-border (regional level) risk management plan. by harmonizing the method of identifying risk assessments to improve preparedness and preventive approaches to the civil protection in cross-border regions.

Acknowledgments
The article was supported EU in type project UCPM-2020-PP-AG, filed under: Number p. 101004823 Networking for Cross-border Risk Management Plan.

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