Creating of Risk Maps

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Abstract. Risk assessment of defined types of hazards and their negative impacts in the territory is the basis for creating risk maps. Risk maps, following up the tasks from the concept of civil protection, will provide quality data for qualified decision-making in territorial planning. The article captures the process of creating risk maps in the Czech Republic in relation to territorial planning and sustainable development of the territory.

1. Introduction
The Czech Republic is confronted with extraordinary events (natural, anthropogenic, combined) where their negative impacts put in danger human life and health, property, infrastructure and the environment. It is necessary to identify extraordinary events that have a negative impact on the safety of the territory. The assessment of individual risks is carried out by the risk assessment, which is a system using certain steps to determine the level of threats caused by incidents. In this context, risk assessment is perceived as an overall process of identification, analysis and evaluation. Risk assessment enables decision-makers and responsible managers (entities) to better understand and perceive the risks. This provides the basis for deciding on the most appropriate approach to be used for risk management. The output of risk assessment is an input into the decision-making processes of public administration. As part of the risk assessment, the risk quantification (risk level) will be final. Using the Geoinformation System is a new approach how to visualize the resulting risk levels into a map background [4, 7]. The resulting level of risk is color-coded on the map, giving the end user a better understanding of the risk context in the territory. In the area of emergency and crisis planning, risk assessment in the territory is an input for planning of civil protection measures, planning of rescue and liquidation work, crisis measures, etc.

2. Risk assessment for map creation
Until 2017, the Czech Republic did not have a consistent approach / methodology for risk assessment. Based on the set task of the Concept of Civil Protection up to 2020 with a view to 2030 0, a document containing the procedures and rules for risk assessment was created. In other words, the Threat Analysis for the Czech Republic (hereinafter referred to as AH CR)0 was created, and it was based on the risk assessment procedure according to ISO 31 000 0.

When developing procedures in the AH CR, the standard 0 states that the risk assessment is trying to answer the following basic questions [3, 4, 5]:

- What can happen and why (using danger identification)?
- What can be the consequences of initiated risks?
- What is the probability of their future occurrence?
- What is the probability of their future occurrence?
- is the level of risk acceptable, or does it require to reduce the level of risk?
A working group was established for the implementation of the AH CR, which created a unified register of 72 dangers in the Czech Republic. At national level, 21 dangers were identified as low risk, 29 medium risk and 22 high risk. Subsequent assignment of the amount of danger with its level of risk was approved by the Resolution of the Government of the Czech Republic. The method includes a summary expression of the adverse effects of the event or phenomenon capable of harming the protected interests. Protected interests are - population, environment, economy and social impact. The multi-criteria analysis used for Threat Analysis is based on the classical expression of the risk of frequency function and consequences. According to the results of the AH CR, 22 types of danger (high risk) with the possibility of declaring a crisis state were identified. For these dangers, measures must be taken to reduce their risks. In the framework of crisis planning, all these potential crisis situations were processed into a new generation of type plans.

3. Visualization of the risk level in the map

A new approach to recording quantified risk is their visualization into maps using the Geoinformation System. This approach is solved in the safety research project VH20182021037 Risk Mapping in the Czech Republic, project duration 2018 - 2021, (hereinafter referred to as Project). The project aims to carry out risk mapping in the Czech Republic using a certified methodology and software tool. The user will be the competent crisis management authorities. The software will enable to carry out threat analyses and use the results when acquainting municipalities and civil population with the nature of potential threats in a specific territory.

Determining the level of risk is based on mathematical expression (1):

\[
UR = \frac{R \times Z}{P}
\]  

Where:

UR – level of risk,
R – risk rate,
Z – vulnerability rate,
P – preparedness rate,

The risk rate is determined from the classical expression of risk as a function of frequency and consequences (result from the AH CR), enriched by more precise coefficients (sources of risk, intensity of threat, security). To determine the level of risk more precisely, other parameters enter the equation - vulnerability and preparedness. These are the values of empirically determined elements that have the characteristics to increase (vulnerability) or, conversely, to mitigate (preparedness), consequences of an extraordinary event see Figure 1.

![Figure 1. Theme of creation of Risk Map [8, 9].](image)

The vulnerability elements of the territory applicable to the Project are divided into the following categories:
• Persons: residents, staff, public spaces,
• Public infrastructure - transport infrastructure: roads, railways, metro, airport, waterways,
• Public infrastructure - technical infrastructure: electricity, public water supply, sewerage, gas pipelines, heat supply system, oil and gas pipelines,
• Public infrastructure - civic amenities: socially important buildings, cultural monuments,
• Integrated rescue system: basic elements,
• Other critical infrastructure: other critical infrastructure elements,
• Industry: industrial and logistics areas and the environment [9].

The elements of preparedness of the territory usable for the Project are divided into the following categories:
• Fire protection units: fire brigade units of the Fire Rescue Service of the Czech Republic, fire brigade units of enterprises, Voluntary units of municipalities,
• Medical Emergency Service: Headquarter bases, Air Rescue Service,
• Internal order and security: Police of the Czech Republic, Air Service of the Police of the Czech Republic, municipal police,
• Population protection means: a uniform alert and information system; and
• Others: hospitals.

![Diagram of vulnerability mapping procedure](image-url)

**Figure 2.** Example of vulnerability mapping procedure 0.
Each element was evaluated by a team of experts using the same principle as the assessment of types of dangers within the AH CR. Individual values of vulnerability and preparedness elements were detailed with more precise coefficients. Specifying Vulnerability Coefficients are Unit of Vulnerability, Intensity of Vulnerability and Security. Preparedness Coefficients are Unit of Preparedness, Intensity of Preparedness and Security [8, 10].

Calculation of risk, vulnerability, and preparedness maps gives rise to maps: danger, vulnerability, preparedness and risk. For example you can see Figure 1 which is diagram creating a vulnerability map. In Table 1 there is step by step explanation of diagram.

| Step | Describe |
|------|----------|
| Step 1 – Vulnerability categories | The Expert Group has identified seven (person, transport and technical infrastructure, civil amenities, integrated rescue system, industry, environment) categories of vulnerability that express areas that may increase the negative impact of an extraordinary event or crisis situation on protected interests. |
| Step 2 – Vulnerability elements | For each vulnerability categories (VC) were indentified vulnerability elements (VE), for example: VC person – VE: residents, staff of objects, public space; VC transport infrastructure – VE: roadway, railway, airport, waterway. |
| Step 3 – Protected interests | Protected interests have been defined in the Analysis. These protected interests are: lives and health of people, environment, property, social stability. |
| Step 4 – Vulnerability level assessment | The vulnerability level assessment was carried out by an expert group which used the same approach as in the assessment of the types of dangers in the Analysis. |
| Step 5 – Vulnerability level variable | Variable expressing the vulnerability of a particular vulnerability element. The vulnerability level represents the level of possible losses and damage to a given vulnerability element. |
| Step 6 – Vulnerability rate | It represents the overall vulnerability of the element. It is Quantitative evaluation of function of vulnerability level and refinement coefficient. |
| Step 7 – Cumulation of vulnerability elements | In this step, the individual degrees of vulnerability elements are summed up, resulting in an overall vulnerability of the territory. |
| Step 8 – The resulting vulnerability of the territory | Expressed by MZ - the rate of vulnerability. The resulting vulnerability rate will be visualized into maps. |

4. Defining standardization conditions for the use of spatial map layers
For the creation of maps are crucial data. Project data will be stored in a spatial database in the form of vector and raster data types respecting the ESRI exchange standard (shapefile, raster grid) and the OGC web services standards are used for data processing and presentation. The ESRI program product known as ArcGIS Desktop and the Python programming language for task automation will be used to prepare and process Project data. One of the main advantages of this solution is the possibility to extend the application in the form of so-called "toolboxes". Most ArcGIS Desktop functions and tools are implemented in the Python integrated programming language into a library called "arcpy". Using this library, you can access various ArcGIS functions to include them in complex spatial calculations or automate the entire data analysis process. Information from risk maps will be used in the process of emergency and crisis planning, but also for spatial planning [4].

5. Link to planning in the territory
Spatial planning in the public interest determines the complex use of the territory and the function of individual parts with regard to the development of municipalities, cities, regions and the state. Land use
planning also includes the efficient use of natural resources, the protection of aquatic ecosystems and the provision of basic living needs of the population. The outcome of spatial planning is the spatial plan, so it is one of the most important documents that can be included in the safety planning of the territory. The territorial analytical data of regions and municipalities are the basis for the analysis of sustainable development of the territory [4].

The results obtained from the created maps will serve for the area of spatial planning especially in the following activities:

• create conditions in the territory to ensure the civil protection;
• examine and assess the need for changes in the territory, the public interest in their implementation, their benefits, problems, risks with regard to public health, the geological structure of the territory, the environment, the impact on public infrastructure and its economic use;
• create conditions in the area for reducing the risk of ecological and natural disasters and for removing their consequences, in a manner close to nature;
• create conditions for the protection of the territory against the negative effects of projects on the territory and propose and compensatory measures.

6. Conclusion

The territory of the Czech Republic is faced with extraordinary events that have an impact on protected interests; on the lives and health of the population, property, infrastructure and the environment. Risk assessment can be used to summarize incidents, their frequency and consequences. The result is a quantitative risk assessment. The level of risk can be visualized into maps using Geoinformation systems. The article describes the creation of maps as a tool for emergency and crisis planning with the use of spatial planning. The resulting risk map is based on the Danger Map, Vulnerability Map, and Preparedness Map. Each map is based on the evaluation of the elements using refinement coefficients. A specific feature is the danger map, which is based on the results of the AH CR with more detailed evaluation based on the use of more precise coefficients. The map of vulnerability and preparedness is based on defined elements (e.g. vulnerability of a person's element, preparedness of a hospital element), their evaluation according to the AH CR and specification coefficients. Data is important for map creation. ESRI, ArcGIS Desktop and Python programming language for automation of tasks will be used for data preparation and processing. The resulting maps will be reflected in spatial planning.

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