CHALLENGES AHEAD THE CREATION OF GEO DATABASES FOR MULTI-RISK ASSESSMENT IN REPUBLIC OF BULGARIA

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ABSTRACT
Dealing with the devastating effects from natural disasters requires implementation of innovative approaches and integrated policies for disaster risk management. The development on the territory of Southeast Europe, including Republic of Bulgaria, is an object of various natural hazards, such as earthquakes, floods, strong winds, wildfires, etc. A number of political instruments of the EU promote development and implementation of integrated approaches for mitigation of the effects from natural disasters on development. The implementation of the European integrated policies by all member-states induces a number of challenges to governments, especially concerning data availability, access and credibility. This publication presents the main problems and challenges related to multi-risk assessment of natural hazards, regarding creation of a data model. Database concepts for multi-risk assessment and mapping shall include sufficient and quality information related to the separate stages of risk assessment - risk identification, risk analysis, and risk evaluation. In general, the challenges related to spatial data for multi-risk assessment and mapping come from the constraint to process, combine and evaluate data with different sources, and formats, which is often different to compare and relate. At the national level, data models face further difficulties of limited access to information, high prices and lower requirements for data quality. The publication presents an approach for multi-hazard risk assessment in Bulgaria, a geo-database conceptual model and the challenges ahead its creation and processing. The data and data sources are evaluated in terms of their quality, availability, input and reliability to the achieved results of multi-risk assessment and mapping in Bulgaria.

Key words: geo database, multi-risk assessment, multi-risk mapping, integrated disaster risk management, R. Bulgaria

INTRODUCTION. MULTI-HAZARD RISK ASSESSMENT
The increasing threat from natural disasters requires the implementation of multi-hazard and multisectoral practices for disaster risk management (Sendai Framework for Disaster Risk Reduction 2015 – 2030). The management of multi-hazard risk is based on multi-hazard and multi-risk assessment which require a complex and comprehensive analysis of wide-range data and parameters. Visualisation of the multi-factor risk through mapping is an advantageous risk management tool. Multi-risk maps are generalised representations of the reality during a disastrous event. Risk maps are elaborated to guide the solution of different problems and are widely used in decision-making. Maps shall be created as simple and user-friendly as possible even when presenting complex matters and interactions. Presenting too much information simultaneously in one image can mislead

multi-risk map users. Therefore, multi-risk mapping shall produce simplified results from complex multi-risk analysis. The risk analysis follows the risk assessment framework, where risk is commonly expressed as in equation (1):

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \qquad (1)$$

Vulnerability could be presented by the interaction of its components ‘exposure’ and ‘susceptibility’ and ‘resilience’:

$$\text{Vulnerability} = \text{Exposure} + \text{Susceptibility} - \text{Resilience} \qquad (2)$$

In the case of multi-hazard risk assessments, hazard encompasses the probability of occurrence of different hazardous phenomena which pose a threat to a certain territory. The interactions between hazards need to be considered in the risk analysis, because the occurrence of a single hazard often affects the magnitude and frequency of another, or is likely to trigger related hazardous process. Furthermore, multiple hazards affect the vulnerability ratio of a territory through the induced changes in exposure and susceptibility to damage in the case of multiple disasters. Since multi-risk assessments present the cumulative effect from multiple hazards on an integrated vulnerability, they require weighting of the analysed parameters. Therefore, the multiple-hazard risk can be evaluated by the following equation:

$$\text{Multi-risk} = \text{Multiple hazard X Integrated Vulnerability} \qquad (3)$$

So far multi-risk management has not been addressed by the disaster risk management framework in R. Bulgaria. The disaster risk management policy of the country addresses the assessment and management of natural hazards separately, disregarding hazards’ triggering effects, interactions and effect on the vulnerability of the exposed elements.

REQUIREMENTS FOR MULTI-RISK ASSESSMENT GEO DATABASES

The purpose of the multi-hazard risk assessment geo database is to collect all the necessary information and required data for the performance of a reliable multi-risk analysis. The International community has not agreed on a common multi-risk assessment framework yet. Therefore, multi-risk geospatial databases can differ significantly in terms of typology, data sources (private or public data owners) and modelling approaches. Nevertheless, multi-risk assessment databases should comply with certain international standards for data collection (sources of information), validation, storage, structure, quality, availability, update and sharing.

First of all, geospatial data should be collected from reliable and official data sources, i.e. statistic agencies at different levels, public registers and data bases, historical records, scientific researches, specialised maps, satellite images, etc. After its collection, it is very important that the raw data is validated and calibrated, so that any primary mistakes and defects are eliminated. Data validation is particularly important when using old databases and maps which are often the only available and affordable source of risk information in Bulgaria. When it comes to data generated by modelling softwares, it needs to be calibrated in order to achieve realistic and reliable results. In countries like Bulgaria, where information related to natural risk is not public or is still classified, it is often necessary to digitalise information from paper maps and other hard copy sources. Digitalisation is often a time- and labour-consuming process which could be an obstacle for risk evaluators with limited financial capacity, i.e. local authorities, researchers, stakeholders, etc.

The multi-risk assessment database should be structured within a conceptual data model which follows an accepted conceptual framework for multi-risk assessment. The frameworks and models often depend on the specifics of the studied area and the available data for multi-risk assessment. The structure of the multi-risk assessment database should allow performance of quick analysis of the input data and detect changes in their behaviour. The stored data shall remain accessible for updating and for the sake of being used in new monitoring software [2]. These specifications of the multi-risk assessment geo database structure make GIS software particularly suitable to perform multi-risk modelling, assessment and visualisation.

Geospatial databases for multi-risk assessment need to be organised and stored in a way that it is available and user-friendly. Multi-risk databases should comply with certain requirements for quality and integrity. Multi-risk datasets include data about various parameters, obtained by different sources and from different owners – private and public bodies. It is hard to coordinate common requirements for data quality and structure between the numerous data owners but certain international standards shall apply to that, for instance, the requirements of the Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community [1]. The Directive sets minimum quality requirements for spatial databases, owned and maintained by member-states. Last but not least, multi-risk assessments should not present static and final results. Most of the required date for multi-risk assessment has a spatial components (demographic, economic, land use and other variables) which changes over time. Therefore, multi-risk databases should be regularly updated and made accessible for different users and stakeholders.

CONCEPTUAL DATA MODEL

The geospatial database for multi-risk assessment contains two main data input modules – the multi-hazard module including the hazard inventory (frequency, range, intensity of hazards' occurrence), and the vulnerability module which includes the vulnerability inventory (exposed objects and their attributes). Adopting the risk-analysis framework of Van Westen, Damen and Feringa 2013, we determine that the multi-risk assessment geo database shall generally include separate but interrelated data modules representing the multi-hazard, multi-vulnerability and multi-risk [4]. The multi-risk assessment geo database, therefore, collects and relates all necessary information from the multi-risk analysis framework, aiming to visualise the multiple-hazard risk and contribute to the development of tools and measures for integrated risk management (see figure 1).

The multi-risk assessment database model includes the modules 'Multi-hazard', 'Multi-vulnerability', 'Risk analysis' and 'Risk estimation'. The multi-risk conceptual data model includes spatial data presented by vectors and rasters, aiming to visualise the multi-hazard and risk for different end-users.

The *Multi-hazard module* represents the hazard-identification and assessment phase and first step of the risk analysis framework. The hazards, likely to affect a certain area can be presented as values of their characteristics which produce a threat for human development – the given intensity (severity) of a hazard within a particular scenario for temporal probability of occurrence. Multi-risk assessments require greater efforts for harmonization of single-hazard data. For instance, temporal and spatial scales for earthquake-hazard assessments differ from those for landslide or flood hazard. Hence, the type of data that is required for parameterisation and calibration of risk models [3] also differs. When assessing the intensity and frequency of multiple hazards, it is important to consider the interactions between hazards and the triggering factors such as intensive rainfall, deforestation, magnitude of earthquakes, volcano eruption, etc. *Sources of information about multiple hazards in Bulgaria*. The multi-hazard inventories can be generated by historical evidence – data from direct measurements of natural phenomena related to hazardous events. Such data records are obtained in Bulgaria by the state network of ground-based and elevated gauging stations. This data is owned by the state scientific institutes at the Bulgarian Academy of Science and is not publicly available but rather provided at a considerably high price. Therefore, the data from direct measurements, which is also the most reliable data for risk assessment, is not publicly available for risk evaluators from scientific institutes, local authorities and other stakeholders in Bulgaria. Records of measurements about certain natural phenomena is available for 30- to 60-year periods before 1989. These data periods can serve as a basis for modelling of the parameters' distribution in the next decades. Modelling, however, requires the use of complex software and skilled specialists which significantly increases the price of multi-hazard risk assessments. Other source of information, if records from direct measurements are not available, is the data obtained by satellite images. The disadvantage of using such remote sensing tools is that they can provide information only about some natural hazards, mostly hydro-meteorological ones, and some geological hazards, i.e. rockfalls and landslides. Another shortcoming of the usage of satellite images is their inapplicability for small-scale hazard assessments, and the high price of the high-quality and high-resolution images.

The *Multi-vulnerability module* represents the exposure analysis in multi-risk assessment (third step in multi-risk analysis) and includes spatial and non-spatial data about the elements at risk, categorised in social, cultural-political, economic, environmental, physical vulnerability classes (dimensions). The social vulnerability represent the socio-economic aspects of vulnerability, for instance, demographic structure of the population (age, education, occupation, awareness and access to information, family structure, etc.), organisation of the population and communities, etc. The cultural-political vulnerability is related to the cultural heritage exposed to risk (physical and metaphysical cultural wealth), and the institutional strength of the political systems (trust in governmental structures, governmental support to disaster risk management, transparency of policies and systems, etc.). The economic vulnerability deals with the exposure of economic activities at risk, e.g. spatial location of economic activities, production of goods and services, etc. Environmental vulnerability reflects the fragility and exposure of natural elements at risk: ecosystems, protected areas, sensitive environments such as forests, wetlands, biodiversity, etc. The physical vulnerability represents the strength and design features of key infrastructural elements at risk, i.e. critical infrastructure (emergency reaction centres, shelters, medical facilities, social and cultural meeting points, etc.), transport infrastructure (roads, railways, airports, harbours, etc.), and facilities and life lines (supply and communication networks, etc.). *Sources of information about integrated vulnerability to multiple hazards in Bulgaria*. The data in this module presents the integrated vulnerability of the elements exposed to multiple hazards in the studied area. Basic data about the location and type of exposed elements in R. Bulgaria can be obtained from various sources: cadastre maps; land use maps; urban plans; building passports; statistical data about social and economic vulnerability indicators at different levels; demographic, socio-political, economic and environmental surveys, etc. The obstacles in obtaining data about vulnerability indicators are often related to restricting regulations about protection of personal data and private property. Indicators related to statistical social and economic parameters at a local level (districts, buildings, households) are not public in R. Bulgaria. Certain indicators are provided with limited access and at a high price. Information about the physical vulnerability can be obtained from small-scale cadastre and topographic maps, some of which remain classified. An alternative tool for data acquisition about social and economic damage is the database of the Centre for Research on the Epidemiology and Disasters (CRED), which collects and stores data about damage from major disaster events at a national level. The international disaster database suffers the disadvantage of being inapplicable for small-scale disaster risk assessments. The CRED database also collects data only about major disasters with low probability of occurrence, according to set requirements for caused loss of life and economic damage.

The *Risk analysis module* represents a vulnerability assessment of the elements, exposed to multiple hazards (fourth step of multi-risk analysis). Vulnerability is analysed and assessed based on a set of vulnerability indicators for the capacity of the exposed elements to anticipate, cope with and recover from natural hazards. This information is added and presented in GIS as attributes to the visualised objects. The indicators for vulnerability assessment must represent objectively different features of all dimensions of vulnerability – social, cultural-political, economic, physical, and environmental. The scarcity and inconsistencies of vulnerability information often makes it the weakest link in a risk assessment [3]. The integrated vulnerability of the exposed elements can be determined and qualitatively assessed according to an adopted risk matrix. The multi-risk analysis is the pre-last step of the multi-risk assessment and results in single-hazard risk maps, based on qualitative risk assessment.

The *Risk estimation module* represents the final step in the multi-risk assessment framework. It aims to provide a quantitative evaluation of the impact from multiple natural disasters on the social-related, economic and environmental elements at risk. Vulnerability is often difficult to quantify, especially when it comes to the social, cultural, political or environmental dimensions. Social, cultural-political and environmental vulnerabilities are difficult to present as monetary values due to the moral aspects of applying values to tangible assets with high immaterial value, i.e. human health and life, cultural monuments, ecosystem functions. On the other hand, the monetary evaluation of the economic and physical vulnerability indicators is difficult due to the privacy of data related to monetary value of private property. Quantitative vulnerability analysis and estimation are often limited and available only for certain indicators of the physical or economic vulnerability, i.e. building value, material and design; loss of economic production, etc.

The information within the multi-risk assessment conceptual data model is structured in layers which visualised in GIS show different features of the multi-hazard and risk and allow spatial analysis of the multiple hazards, vulnerability and risk (figure 2). The creation of multi-risk assessment database should follow the logic of the conceptual data model and include data, organised according to the multi-risk assessment modules, containing spatial components (areal, points, objects) and their multi-risk related attributes (table 1.).

Table 1. Contents of the geo database

Attribute	File description	File format	Geometry
Multi-hazard module			
Hydrological hazards			
Flood	Indicators for river floods	Vector	Polygon
	Indicators for tidal floods	Vector	Polygon
	Indicators for torrential floods	Vector	Polygon
	Indicators for urban floods	Vector	Polygon
	…	…	…
Mass movement (wet)	Indicators for rock mass falls	Vector	Polygon
	Indicators for landslides	Vector	Polygon
	Indicators for avalanches	Vector	Polygon
	…	…	…
Meteorological hazards			
Extreme weather	Indicators for tropical storms	Vector	Polygon
	Indicators for extratropical storms	Vector	Polygon
	Indicators for local storms	Vector	Polygon
	…	…	…
Climatological hazards			
Extreme temperature	Indicators for heat waves	Vector	Polygon
	Indicators for cold waves	Vector	Polygon
	…	…	…
Drought	Indicators for drought hazard	Vector	Polygon
	…	…	…
Wildfire	Indicators for wildfires	Vector	Polygon
	Indicators for fieldfires	Vector	Polygon
	…	…	…
Multi-vulnerability module			
Social vulnerability	Indicators for: potential damage (exposure), copying capacity (susceptibility), capacity to recover (resilience)	Vector	Point/Polygon
Cultural-political vulnerability		Vector	Point/Polygon
Physical vulnerability		Vector	Point/Polygon
Economic vulnerability		Vector	Point/Polygon
Environmental vulnerability		Vector	Point/Polygon
Risk Analysis Module			
Hydrological vulnerability assessment	Integrated vulnerability to hydrological hazards	Table/ Vector	Point/Polygon/No geometry
Meteorological vulnerability assessment	Integrated vulnerability to meteorological hazards	Table/ Vector	Point/Polygon/No geometry
Climatological vulnerability assessment	Integrated vulnerability to climatological hazards	Table/ Vector	Point/Polygon/No geometry
Risk Estimation Module			
Multi-risk assessment	Integrated social, economic and environmental impact (estimated loss)	Table/ Vector	Point/Polygon/No geometry

*The table is elaborated by the authors

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The major challenges for creation of multi-risk assessment databases in R. Bulgaria are related to the private status and high price of the data both for the hazard and vulnerability indicators. The unavailability of data about natural phenomena and hazards for recent periods require modelling and calibration of the results which are specialised tasks, which depend on the use of expensive software and skilled experts. Local authorities, stakeholders and even scientific institutions in R. Bulgaria often cannot afford to perform risk modelling. When it comes to the evaluation of vulnerability indicators, data is often unavailable due to privacy restrictions, classification, or high price of statistical parameters. The lack of publicly available and affordable data is among the reasons for the limited existing scientific research in the field of multi-risk assessment in the country. The current situation in R. Bulgaria is unfavourable not only for scientific researchers and local authorities who aim at assessing risk, but also with regards to the implementation of European political frameworks for data quality, availability and maintenance such as the INSPIRE Directive. Currently, Bulgaria is not complying with a number of the requirements set by the Directive, among which: the necessity for 'spatial data collected at one level of public authority to be shared between other public authorities'; spatial data shall be 'made available under conditions which do not unduly restrict their extensive use' (6); 'Where a public authority supplies another public authority in the same Member State with spatial data sets and services required for the fulfilment of reporting obligations under Community legislation relating to the environment, the Member State concerned should be free to decide that those spatial data sets and services shall not be subject to any charging' (23).

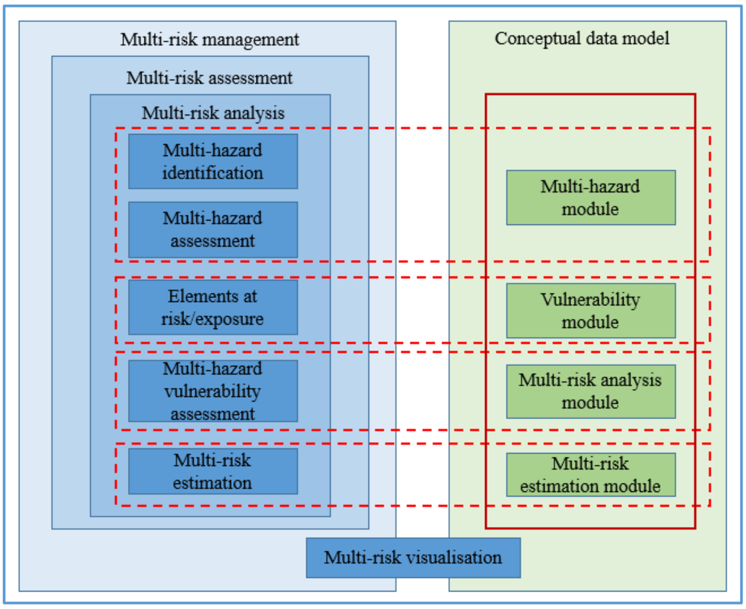

Figure 1. Conceptual framework for multi-hazard risk assessment, bound up with the multi-risk management framework of Van Westen, Damen and Feringa 2013