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MAPPING NATURAL DISASTERS FOR PREVENTING THEIR CONSEQUENCES (REVIEW ARTICLE)

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SUMMARY

The necessity of exploring the territories affected by disasters requires the use of different maps at all four stages of the disaster management cycle. This paper presents the importance and use of cartography products in natural disaster management (DM) in its phases: mitigation, preparation, response and recovery. Natural disasters are briefly described in order to outline the need for different cartographic representations depending on their specific features. Approved and new methods of mapping natural disasters are examined and classified. A new classification is proposed following their use before, during and after the catastrophic event. Since the climate in Bulgaria presupposes an increased risk for forest fires, they have been studied in detail. Good practices in forest fire management worldwide are considered on the basis of which some future work in this respect could be planned.

Key words: natural disaster, mapping natural disasters, disaster management, forest fire.

1. INTRODUCTION

Disasters happen almost daily somewhere around the world. Some of them are natural, others are the result of human activities and in most cases, no matter what type of disaster occurs, they catch the society off guard. During the last decades climate change is considered to be a major cause for natural disasters, enhanced by the consequences of vast urbanization worldwide. Although the advanced technologies and science have improved disaster prediction over recent years, natural disasters still cause enormous damages: human fatalities, economical losses and ecosystem degradations. According to Intergovernmental Panel on Climate Change, improvement and

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strengthening of the measures for coping with these events is still needed in the future (IPCC 2012).
The European Environmental Agency published a technical report which discusses the occurrence of natural disasters in Europe and their social and environmental impacts for the period 1998 - 2009. This document summarizes statistics, proposals for measures and policies for reducing the impacts of the most frequent disaster events in Europe. Statistics show that they caused nearly 100 000 deaths and affected the lives of more than 11 million people in Europe for that period (EEA 2010). Since post-disaster relief became a necessary but insufficient measure, disaster management policy has been oriented more to the mitigation and preparedness processes.
To reduce the impacts of disaster events in Europe, experts started to use an approach which includes the four stages of disaster management cycle, namely, the Integrated Risk Management (IRM) involving actions for mitigation, preparedness, response and recovery.
Cartography and the related disciplines, Geo-information Systems and 3D Modeling, are an inseparable part of the disaster management cycle in which their products are successfully used at every stage. Marinova (2010) points out the use of cartography in disaster management:

- Before the catastrophic event: for assessment and preparedness;
- During the catastrophic event: for protection;
- After the catastrophic event: for recovery actions.

A variety of maps provide important and specially selected data for different groups of users: experts and non-experts, adults and children, rescuers and victims. Bandrova and Konecny (2006) suggested that the future maps used in disaster management should be more schematic and created especially for the user's needs. Mobile and electronic technologies should also be involved in the mapping process. The variety of cartographic products used for preparations before the disaster, for decision making during the rescue operations and damage assessment after the event are necessary and irreplaceable tools in disaster management.
To analyse in detail the meaning of cartography during such crises, the types of natural disasters are reviewed. This review aims to present the natural disasters in a global perspective and according to the climate and locality, narrowing them down to a continental and local level. Focusing on the most frequent natural crisis events for Bulgaria, various methods of cartographic representation are examined and a generalized classification is made. The available map products for disaster management are briefly reviewed. Special attention is paid to forest fire incidents, considering good practices in management in which the diverse use of maps improves the processes: preparation, decision making, emergency rescue, etc.

2. TYPES OF NATURAL DISASTERS

EM-DAT stands for International Disaster Database which is developed and maintained by the Centre for Research on the Epidemiology of Disasters (CRED). This database provides standardized data compilation and is known as the international source of free disaster data for decision-making, vulnerability and post-disaster damage assessments etc. (EM-DAT 2015a). In 2007 EM-DAT and Munich RE implemented a new common and comprehensive classification of disaster events which later on was accepted and established by other institutions - Swiss RE, Asian Disaster Reduction Center and United Nations Development Programme. Until then the lack of standardized classification and terminology led to poor interoperability between the different databases Therefore, the main aim of the new classification was to be recognizable and applicable internationally. This classification (fig.1) divides the disaster cases into two main groups: natural and technological. Natural disasters form six groups: Biological, Geophysical, Meteorological, Hydrological, Climatological and Extra-terrestrial. The classification is narrowed down to sub-types and sub-sub types of disaster events according to the triggering hazard (Wirtz et al. 2009).

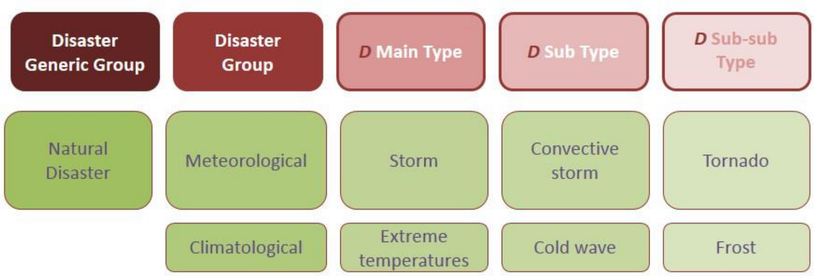

Fig. 1 An example of one row of the EM-DAT classification.

IDRD (Integrated Research of Disaster Risk) developed another classification of the natural disasters which is specially designed to serve to multiple types of loss databases. Despite the proposed structure contains the basic features of EM-DAT's, it has peculiarities. In this classification the disaster types are subdivided into families, main events and perils (fig.2). However, the families in this case are similar to the types of EM-DAT's and the main type of disaster corresponds to the main events, the disaster sub-types and sub-sub types here are combined at one level, i.e. perils. In the proposed framework perils are not strongly distinguished and this is the

reason to consider that classification as ore flexible than EM-DAT's classification. The connections "perils - main events" are one-to-many which requires that the perils should be related according to the particular case. These improvements in the IDRD classification affect not so much the global level as the national and sub-national level loss databases (IRDR 2014).
n this paper the EM-DAT classification will be assumed to be a generic classification.

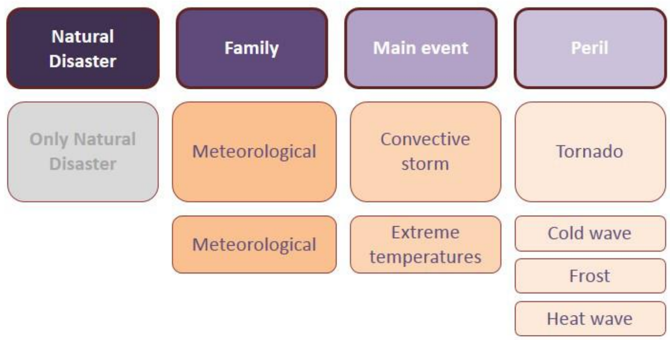

Fig. 2 An example of one row of the IDRD classification.

Conditions such as location, weather and tectonic plates are strongly related to the types of disaster and their occurrence. Reasonable disaster management requires focusing on the hazards on local level in order to take proper measures for mitigation, preparedness, response and recovery. Disaster events should be examined in the world statistics but the more reduced a disaster classification is, the closer the concrete problem solutions are. If an examination of the types of natural disasters is made locally in Europe, the worldwide classification of EM-DAT, consisting of over 28 sub types and sub-sub types, will be reduced to 8 major natural disaster events. If the examination is narrowed down to Bulgaria, two of Europe's most frequent disasters will drop out of the picture (fig. 3).
According to EM-DAT statistics of major natural disaster events in Europe for the period of 2004 to 2014, the most frequent natural disaster is flood followed by storms. However, frequency should be not considered separately from casualties and economical losses. During that period extreme weather events caused over 63 000 fatalities and next on the list are floods with over 1 000 (EM-DAT 2015b). Although significant earthquakes do not occur so often, the devastating consequences for the population and the economy list them among the most catastrophic events.

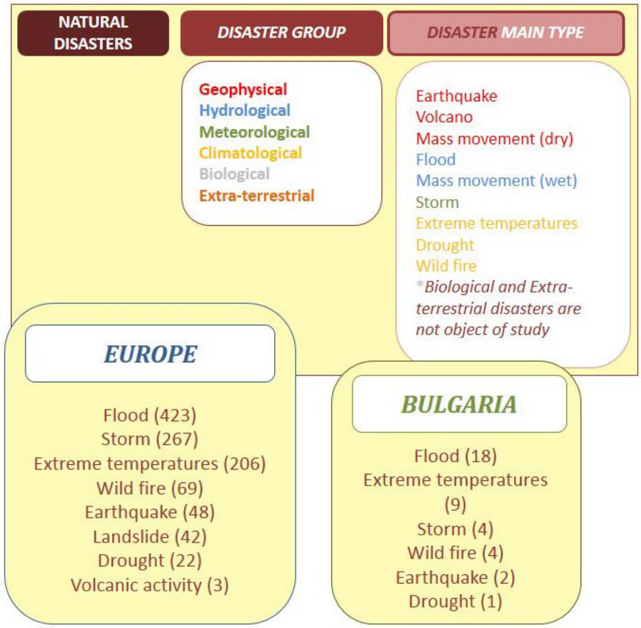

*Fig. 3 Reducing the disaster classification according to locality***.**

Natural disasters often occur in Bulgaria, the most devastating ones being floods, storms, landslides, earthquakes and forest fires. Every summer the hot temperatures and the human neglect are the reasons for the initiation of forest fires which spread over hectares, damaging habitats and causing environmental degradation. For the ten-year period (2005 - 2015) 29 disaster events were registered in EM-DAT's database. In terms of numbers, 159 people lost their lives (EM-DAT 2015b). This amount of casualties cannot be underestimated having in mind that the population of the country is around 7 million. Only in 2014 four floods hit different regions causing human fatalities, collapsed houses and huge economic losses. In 2015 snowstorms blocked part of the country leaving thousands of people without food, medicines and electricity for days on end. The heavy snowfalls combined with rains caused floods and initiated landslides and rockfalls, blocking roads. Obviously, there is an urgent need for improving the disaster management actions in Bulgaria and especially in the pre-disaster and disaster phase in order to reduce the hazard of such events. Special attention should be paid to the huge set of mapping methods applied worldwide, which, if used properly, can improve the processes in the four stages of disaster management cycle.

3. METHODS OF MAPPING NATURAL DISASTERS

In this paper section a classification of the cartographic methods which are commonly used in the disaster management is made (fig. 4). The methods are categorized to four main groups. Three of them are following the recent technological trends: Remote Sensing (RS), GIS Analyses and 3D modeling and the other is the group of traditional cartography methods which are still not fully replaced by the modern and also provide map products for DM. The classification is based on the differentiation of the methods, according to their use in the stages of the disaster event. The four stages of the disaster management cycle requires different cartographic methods which are applied before, during and after the catastrophic event.

	Remote sensing	GIS analyses	3D modeling	Traditional cartography
Before the event	**Hazard**, risk and vulnerability assessment mapping; **3D** data collection and DEM derivation; **Pre-disaster** mapping	**Vulnerability** and risk modeling; **Disaster** simulations.	**3D mapping** for mitigation and prevention; **3D animations** for disaster simulations; **Virtual Reality** for disaster response trainings.	**Hazard**, vulnerability and risk mapping; **Disaster** mapping, according to statistical data; **Mapping** of rescue and escape plans.
During the event	**Near-real** time or rapid mapping; **Mapping** inaccessible locations.	**Disaster** simulations; **Spatial** analyses; **Evacuation** and rescue simulations.	**3D** thematic visualization for decision-making.	**Mapping** for planning rescue operations
After the event	**Damage** assessment mapping; **Mapping** inaccessible locations.	**Damage** assessment modeling; **Compensation** assessment modeling.	**3D** realistic visualization for recovery activities	**Damage** assessment mapping; **Mapping** for recovery activities.
	Combinations			

Fig. 4 Methods of mapping natural disasters, according to their use in the different stages of the catastrophic event.

3.1. Remote Sensing

Remote Sensing (RS) is irreplaceable tool in the DM, because of its ability to provide spatial data for huge areas in a short time anywhere around the world. Moreover the Remote Sensing equipment provides data via various technologies which cover the specific needs of specific data, according to the event. Many examples can be given in order to approve the huge contribution of RS in crises management: from imagery interpretation for monitoring and risk mapping to rapid mapping during the disaster, RS provides large range of detailed data needed for reasonable disaster management.

Remote Sensing provides the opportunity of rapid mapping or mapping soon after the disaster hits. This method of rapid cartography is crucial part of decision-making processes for emergency and rescue operations. Buehler and Kellenberger (2007) present framework of rapid mapping in order to improve and optimize the process of the International Charter: an organization, which provide a unified space data to the affected by disasters (International Charter, 2015). Kerle et.al (2008) make a detailed review of the airborne sensor data and its use in different disaster scenarios.

Although Remote Sensing do not have all the functionalities of GIS and 3D modeling, it provides huge variety of data which is successfully applied as a base for further analyses via these methods. RS is a good example of showing the existing interconnection and cooperation between the different methods for disaster mapping. Dorn et.al (2014) effectively combines OpenStreetMap vector data, LIDAR point cloud, orthophotos, land use and land cover data to create flood simulations in GIS environment for a study area in Austria.

3.2. GIS analyses

The Geographic Information Systems already have a high value in public service for more than 20 years and they are still being constantly improved to meet the users' needs. The opportunities they provide are turning them into invaluable method for disaster mapping. GIS could be applied equally well before, during and after the disaster emergency.

In the phases of mitigation and preparedness the GIS methods are used mostly for risk assessment and disaster simulations. The environment of GIS does not constrict the opportunities and the diversity of parameters which can be used for problem solving in the disaster management. One of its most common uses in the first two phases of the disaster management cycle is the flood modeling. Two different study cases shows similar approaches over the coping with the disastrous flood events. Liu and et.al (2005) and Kia et.al (2012) study the potential impact of the changing from rural to urban land use to the watersheds and assess the risk of floods based on parameters such as canopy, soil surface, soil, rainfall quantity and groundwater. As oppose the work of Dorn et.al (2014) mentioned already, is more focused on studying the meaning of inundation area, water depth and flood intensity over the flooded area. Another good example of risk modeling is the forest fire risk assessment. This is deployed in details in Chapter 4.

During the disaster GIS methods provide fast and crucial information important for the decision-making process. Their huge role lays on the strength of the spatial analyses and the real-time data collection. Cases of poisonous gas leaking, explosions, terrorist attacks, forest fires and floods can be easily followed and kept under control. The tools, such as finding the shortest or the fastest route, calculation of the affected area and the number of the citizens who must be evacuated, contribute for smarter and better response in cases of emergency. The use of variable parameters, such as real-time traffic information, helps for better planning and faster decisions when there is a time limit and people are in danger.

Nowadays people are turning to social media to get current information and updates over important topics and news. One of the last innovations in GIS is to include the social sharing as a powerful instrument for collecting real-time data by tracking the posts of users reporting their close experience with the disaster event. The products are constantly updating interactive maps available on-line. For instance an examples of a real-time social media mapping is the Esri's map of Napa earthquake based on the websites: Twitter and YouTube (Kerr, 2014). Velev and Zlateva (2012) point out that receiving data is not the only use of social media in the disaster management. According to their work these networks are also available for broadcasting real-time information to the affected people and can be used for optimization of the recovery activities and immediate relief efforts.

Last but not least GIS analyses are suitable method for damage and relief assessment. In the fourth stage of the disaster management cycle - the evaluation of the affected people, buildings and infrastructure can be followed by a classification according to parameters which ease the processes of the recovery actions. Depending on the tasks assigned by the specialists to the GIS products, the recovery stage can be separated on two types: short-term and long-term recovery (Johnson, 2000). The short-term includes damage assessment, shelter accommodation, medical help, etc. and the long-term recovery is focused on restoring the normal life flow. The last one may take a couple of months up to few years.

3.3. 3D Modeling

One of the best features of the 3D modeling is that the products are more intuitive and the information that they represent is perceived in much easier way from the user than the 2D maps. The 3D models do not require special education and preliminary training which makes them suitable for any age. These qualities expand the opportunities for simulations and trainings with educational purpose: an essential part of the preparedness phase. However the 3D maps should not be considered as universal maps. Like every other cartographic product they should be user-oriented and should be prepared in consideration of requirements depending on the specific theme. According to Bandrova et.al (2012) there are still some unresolved issues with the creation of 3D maps for disaster management. Great amount of data and time is still needed to build an accurate and user-oriented 3D map. The other problem that is examined is the lack of standardization which leads to non-compliance with the main requirements for cartographic products such as map symbology, data classification, etc. With no doubt the 3D modeling products can be successfully used in the disaster management but the time consuming preparation limits their availability in emergency cases. In time of disaster the 3D models or the 3D maps has to be already created in order to be used for urgent decision-making. The quality of the decisions which will be made by this method during disaster, will depend on the content and the Level of Detail of the model. Attention have to be paid over the quality of the data and the suitability for resolving the task. During the recovery activities the 3D modeling can take a huge role in order to assist the reconstruction of buildings and infrastructure.

The fast developing computer graphics and cognitive science moved the 3D modeling to the next level – Virtual Reality. This have made the virtual reality trainings for disaster response one of the most effective tools for teaching people the best response practices. Virtual Reality gives the user not only the experience of real 3D environment but also the opportunity to take decisions and to be responsible for them. Hsu et.al (2013) examine different VR-training for disaster response applications in order to show all the advantages and disadvantages compared with the traditional class and web trainings. The slightly different type of reality: the Augmented Reality (AR), which according to Milgram at al. (1994) is placed somewhere between reality and virtuality, is also taking its place in the disaster response education programs (Savova 2016). The interesting mixture between virtual and real gives a fun and easily perceptual way for disaster representations for children.

3.4. Traditional cartographic methods

The traditional cartographic methods are the oldest ones and lay the foundations for the new technologies like GIS and 3D Modeling. Over the years the development of the technologies has slightly displaced the creation of the traditional paper map and not only for disaster management but overall. Nevertheless it is still in use for all of the tasks the other methods resolve – risk mapping, damage mapping, mapping for recovery activities, etc. The traditional cartographic methods are popular for representing a historical data for studied area. This kind of data representation is in great help with the activities before a disaster event occur. Based on the historical data and the map representation, conclusions can be made and further preparedness measurements could be taken. Although the GIS methods are the fastest for deriving analytical results and pre-prepared decisions, it has to be admitted that in case of disaster emergency, people are not turning to them at first place. One of the first things the children learn at school is, in case of disaster, to look and follow the evacuation and escape plans in the building, which are products of the traditional mapping methods. The paper map is one of the crucial tools for presenting the disasters and the consequences from them to children and students in educational programs.

4. FOREST FIRES: A CASE STUDY IN MAPPING NATURAL DISASTERS

Around the world, forest fires have detrimental impacts on economies, human safety and health. The damages which they inflict on the environment and society are comparable to the severity of other natural disasters. Forests can be compared with the skeleton of the soil, therefore the healthy forest keeps from other disasters as floods, avalanches, landslides. Recent example of their importance is the huge flood in June 2014 (Varna, Bulgaria) caused 11 fatalities which is considered to be triggered by illegal deforestation. Another important role is the role of windshield. To go deeper in the problem forests should not be considered only as a vegetation canopy but as a living ecosystem with easily disturbing dynamics and a habitat of countless types of species. Responsible forest protection and forest fire management, inseparable part of which is designing valuable and useful maps, must be applied in order to reduce the impacts of these natural disturbances.

4.1. Fire risk assessment

Fire risk prevention and early warning systems for fire detection are crucial for territories like the Mediterranean region where high fire danger conditions: high temperatures, drought, low relative humidity and presence of wind, contribute for fire ignition and fast fire spread. Bulgaria's closeness to the Mediterranean is a prerequisite for an increased risk of forest fires as well as forest is over 30% of its area. These are enough reasons this problem in Bulgaria to be topical and not to be underestimated. Good practices worldwide should be examined and applied in order to improve the management methods and processes in the country.

Crucial part of the fire risk assessment is the determination of the variables which can possibly contribute to fire ignition and spreading. The implementation of these variables in modern cartography and GIS as risk and phenomena modeling gives the opportunity of producing large range of map products usable before, during and after the catastrophic event. Chuvieco et.al (2005) examined the variables and proposed a method of fire risk assessment: Wildland Fire Danger assessment or WFDA which distinguish two components: ignition danger and propagation danger. The method aims to integrate the most important factors connected with fire ignition and spreading into one danger index (fig. 5). Krisp et.al (2005) focused their study on improving fire and rescue services in urban areas, proposing a method of explorative spatial analyses based on population density and incidents occurrence mapping. In other research Chuvieco and Justise (2010) examined in detail the human factors and the relationship between humans and forest fires. Another research studied the connection between the informal settlements in South Africa and the increased fire occurrence (Smith, 2005). Camaro et.al (2013) present another classification of fire risk factors, according to their time variability which divides them on two main groups - long-term and short-term.

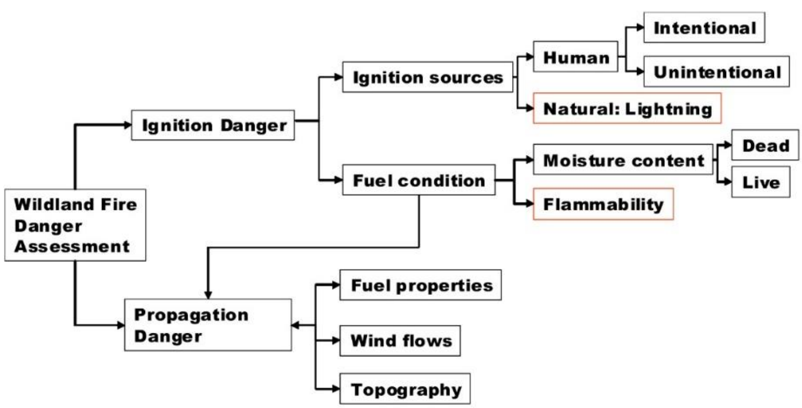

Fig. 5. Structure and components of the Wildland Fire Danger assessment (WFDA) (Chuvieco, 2005)

4.2. Methods of mapping forest fires - risk mapping and forest fire behaviour modeling

Despite of the type of disaster, risk and vulnerability mapping are constituent part of the mitigation stage. Risk mapping is a method which studies the spatial distribution of fire risk. The method requires mathematical integration of many variables to one or several risk indexes which interpolation is made and represented on different map products.

The obvious advance of using GIS and Remote Sensing in disaster management of forest fires, explains the many examples of applicable risk models and maps. For a case study in Garhwal Himalayan region (Chandra, 2005) a technology, combining GIS and Remote Sensing is proposed. The method is used for identifying and different fire risk zones and it is based on the mapping of factors such as forest density and type, aspects, slopes, elevation (extracted from Digital Elevation Model), drainage and human factors, especially remoteness from settlements and roads. Every parameter is assessed with fire risk value. Each value is assigned with weight factor and takes part in the equation of the complex index - Fire Risk Zonation Index.

Guettouche et.al (2011) proposed another methodology of calculating risk and vulnerability indexes. The main difference between this and the previous example is that in this case the climate conditions are considered including three separate indexes, describing the weather factor: climate drought index, index of continentality and index of dry wind. The last stage of the process is combining hazard and vulnerability data for calculation of fire risk degree.

Another technology of mapping forest fires is based on analyses of fire spreading under various conditions. The phenomena is object of study for decades and there are existing forest fire spread models which describe and predict its behavior, according to factors such as fuel features, wind and slope etc. Rothermel's (1972) and Albini's (1976) are still preferred for analyses and calculations. They are also used as base for further developed models such as FARSITE (Finney 1998), etc. The recent years, topical theme is the implementation of such models in GIS environment. The integration between the theory of forest fire behaviour and the opportunities that GIS gives for spatial analyses has evidently improved the processes in the disaster management of such events. Prediction of the spread speed and direction, according to external factors such as wind, fuel type, slope and aspects, etc. takes crucial part not only in the evacuation and rescue but also in a fire fighting operations.

Condorelli and Mussumeci (2009) implement in GIS Rothermel's fire spread model for two regions in Sicily. The implementation is performed with several GRID themes, each of which represents an interpolation of variable in Rothermel's equation. As a result a new GRID is obtained, every cell of which represents the potential spreading speed of the fire front in meters/minutes. This GRID they use for further analyses of the time of spreading and identification of the most probable path of the forest fire. The study of Kanga et.al (2014) presents the successful application of FARSITE and remote-sensing imagery in forest fire risk assessment. In this case the research is focused on using fire spread model for identification of potential fire ignitions, according to fuel, weather and other conditions.

CONCLUSIONS

The society is advancing slow but steady in the process of reducing the losses, both human and material, results of the uncontrollable disaster occurrence. The cartography and the interconnected disciplines have an important role in the disaster management activities by giving suitable data representation, spatial solutions and pre-prepared decisions in a short time or in other cases for detailed 3D environment mapping used for simulation and disaster recovery trainings. In order to use these methods reliably a special attention should be paid to the classification of the disaster types. For better management actions the worldwide list of disaster types should be narrowed down according to the specifications of the area on which they are applied. The disaster management in Bulgaria should note the good practices from the other parts of the world and should consider implementing them in order to improve the actions taken in such emergencies to minimize the casualties and the damages in our country.

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