

## RISK MANAGEMENT IN THE CONTEXT OF MULTI-RISK ASSESSMENT

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**Abstract.** *The late 20th and early 21st centuries were marked by sudden and rapid changes, including the free flow and interconnectedness of people, information, and trade, but the most prominent changes pertain to scientific and technological advancements. New connections were also found between different scientific disciplines, which had previously been considered unrelated, thus causing the breakthrough of multidisciplinary sciences. Unfortunately, the 21st century has so far been ridden with natural disasters worldwide. According to EM-DAT (Emergency Event Database 2015), the consequences and losses caused by natural disasters have been increasing. Thus, risk assessment became a priority for reducing the risk from natural disasters. Risk assessment is the essence of risk management. Just as there are connections between various scientific disciplines, so are there connections between various disastrous events, which resulted in the increased importance of the concept of multi-risk. Multi-hazard risk assessment is a key step in integrated risk management. Over the last decade, the interest in multi-risk assessment has grown in Europe but also globally.*

**Key words:** *natural disasters, risk, risk assessment, multi-risk*

### 1. INTRODUCTION

Many world regions are exposed to various types of hazards. Thus, risk assessment requires the analysis of multiple risks, which could explain the potential interaction between different threats (multi-risk), including cascading events. Today, multi-risk analysis poses a great challenge. The interest and reference to the concept of multi-risk were first registered in Agenda 21 at the UNEP 1992 conference in Rio de Janeiro [19], followed by the Johannesburg Plan of Implementation of the World Summit on Sustainable Development [18], which proposed a new approach to disaster management

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and risk reduction through multi-hazard risk (multi-risk) assessment. Afterwards, there have been a growing number of initiatives for the analysis of multiple risks stemming from different hazards and affecting numerous exposed elements [11]. This is supported by UN data [7], which provide strong evidence of multi-hazard risk across numerous world regions, where the impact of a single hazardous event often becomes more severe through interaction with another hazard, while some hazardous events occur one after the other with no apparent common cause. Risk assessment is the essence of risk management [11]. Therefore, multi-hazard risk assessment has become the primary concern in the field of risk studies.

The United States Federal Emergency Management Agency developed the Hazus GIS method [9], which enables the assessment of potential losses due to multiple individual hazards (e.g. floods, hurricanes, and earthquakes), all for the purpose of more efficient planning, management, and recovery. The losses estimated using the Hazus method include structural (commercial and residential buildings) and infrastructural physical damage, economic losses (lost jobs, going out of business, and reconstruction costs), and social impact (need for shelter, displaced households).

CAPRA software was developed by the Central American Coordination Centre for Natural Disaster Prevention (CEPRENAC) in cooperation with the governments of Central America, the UN Office for Disaster Risk Reduction (UNDRR; and its International Strategy for Disaster Reduction – ISDR), the Inter-American Development Bank, and the World Bank. The software is used for analysing earthquakes, hurricanes volcanic activity, floods, tsunamis, and landslides in Central America. Furthermore, it allows the comparison of multiple hazards while also taking into account secondary hazards resulting from earthquakes, extreme precipitation, and hurricanes (i.e. tsunamis, landslides, and floods).

In addition to multi-risk assessment methods, over the last decade finances were also provided for different European multi-risk analysis projects and for the development of a general methodology for such analysis. The analysed European projects focus mainly on the assessment of natural (e.g. droughts, avalanches, earthquakes, floods, landslides) and technological hazards (e.g. hazards in air transport or in nuclear power stations). In fact, hazards stemming from climate change (e.g. sea level rise, droughts, floods, erosions) are considered only within the CLUVA project. Analysis of the flexibility of their implementation has revealed that most of these projects focus on multi-risk analysis of natural and technological hazards in separate case studies, whereas only projects such as ARMONIA and MATRIX aim to develop general methodologies that are applicable to different case studies and to various hazards. The strength of these approaches is that they try to develop general guidelines, which could then be adopted and improved by the experts dealing with the issues of multi-risk.

## 2. RISK ASSESSMENT

Disaster risk reduction is directly dependent on proper risk management. Risk management as a discipline incorporates prior disaster preparation, disaster response, and support for the community after a disaster. Risk exposure can be measured in terms of probability, frequency, and hazard intensity, which is why risk assessment is a crucial aspect of risk management. Risk assessment is a prerequisite for decision making,

selection of priority projects, and planning of risk reduction measures and identification of areas with low, medium, or high levels of risk in the risk management activities [20].

Risk assessment involves three steps: risk identification, risk analysis, and risk monitoring. The three steps often overlap and the beginning of a subsequent step does not depend on the completion of the previous one.

Multi-hazard risks represent the overall risks to which the population is exposed [2]. The multi-hazard approach is important not only in terms of obtaining the overall risk, but also because of its significance for natural disaster risk assessment and for the planning of efficient countermeasures, to be taken so as to avoid the 'trap' of reducing the risk from one while increasing the risk from another disaster [1]. Many regions around the world are exposed to multiple natural hazards, and efficient risk reduction is possible only if all relevant threats are included in the analysis [10]. Nevertheless, as opposed to individual risk analysis, multi-risk analysis is a more complex process, because every risk possesses its distinctive properties, which are monitored individually [8].

According to the British Department for International Development [5], multi-hazard risk assessment contains the following stages:

1. Hazard/source of hazard identification (involves the identification of hazard source and location; marking of unwanted events and their development; definition of a possible individual or multiple development scenarios, beginning with the main event and the assessment of possible cascade effects);
2. Vulnerability and exposure analysis (involves the definition of hazard exposure of different areas; determination of the probability of a cascade effect; analysis of identified vulnerable elements, such as people, infrastructure, and historical or protected structures),
3. Risk assessment (involves the definition of risk types; assessment of damage scope; assessment of the probability of individual and multiple risks; comparison between the values of multiple and tolerable individual risks);
4. Overall risk impact assessment (in terms of economic, social, environmental, and political impact).

### 3. SERBIAN LEGAL FRAMEWORK FOR RISK ASSESSMENT

Considering the need of every responsible society to continuously improve its degree of resilience to disaster hazards and threats, and the fact that such threats are globally ever-increasing over the last decade and will continue to increase, it is necessary to re-examine the needs and possibilities for improving the existing safety and rescue systems in Serbia.

The existing system was established according to the principles stipulated by the Law on Emergencies [16], which laid the foundations of the unified (integrated) system, identified the subjects and assets of the system, and defined the position and role of each subject, from the Government through authorized bodies to the individuals. The system has faced immense challenges. Previous experience, primarily those gained during the disastrous floods of 2014, but also during smaller-scale events that followed, indicate that the current Serbian legislation is still somewhat limited, that implementation remains slow, and that Serbia remains focused on disaster response, while the concepts of disaster preparedness and risk reduction have to be improved. This primarily refers to insufficiently raised awareness of

the importance of prevention and the lack thereof, undertaken by the subjects of the system. Knowledge and understanding of different risks are crucial for the identification of their causes and for disaster planning and response. There are very few local self-government units and companies that have so far performed a disaster risk assessment and devised a safety and rescue plan, which are the basic documents for efficient risk management.

The adoption of the Law on Disaster Risk Reduction and Emergency Management [15] will improve the general framework for establishing an efficient integrated system for disaster risk reduction and emergency management, with the goal of reducing existing risks, preventing future risks, and responding to emergencies more efficiently. In addition to the aforementioned Law, another legal act was also adopted – the Methodology for Developing a Threat Assessment for Natural Disasters and Other Accidents and Emergency Safety and Rescue Plans [17]. The Methodology was adopted in order to determine the uniform criteria for developing the assessment, to increase quality, to make the data comparable, and to improve the databases on disaster risk and other accidents in Serbia. The threat assessment identifies the sources of possible threats, considers potential consequences, and analyses the needs and possibilities of implementing safety and rescue measures and tasks for natural disasters and other accidents.

According to this methodology, the purpose of risk assessment is to determine the nature and level of risk from a potential hazard, the threat status, and the consequences that could endanger human life and health, property, and the environment. It is a process that includes risk identification, analysis, and evaluation. The assessment should contain the descriptions of every scenario for every hazard the task group selected, the context in which the scenarios were considered, the results of risk calculation and risk level (risk matrix), and the map of all risks. Finally, the risk is evaluated by comparing the results of risk analysis, so as to provide a clear picture of whether the risk is acceptable or whether specific measures need to be taken to reduce it. The Methodology also covers the identification of risk combinations or multi-risk: during risk assessment, the possibility that individual hazards do not individually affect the protected values is taken into account. If, during risk assessment, it becomes evident that any individual hazard has a higher likelihood of occurring or affecting the protected values and that harmful events might multiply and escalate the consequences, such risk is treated with the highest priority and all the necessary resources are deployed, because the potential hazards are combined. Multi-risk is a combination of two or more potential hazards if:

1. They occur concurrently or consecutively;
2. They depend on one another or if they are not caused by the same event or trigger event;
3. They pose a threat to the same elements (vulnerable/exposed elements) without a chronological coincidence.

Concurrent multiple hazards are also called concurrent events, destructive effects, domino effects or cascade effects (for instance, an earthquake may cause a gas pipeline explosion or an industrial accident can cause a fire). That is why multi-risk analysis considers the interdependence of several potential hazards and risks. Any event or potential hazard can instigate even more potential hazards, each of which can be considered separately. The probability of occurrence of any of these events is naturally closely connected to the probability of occurrence of a subsequent event or a previous triggering event. Consequence

assessment, therefore, has to consider the cumulative impact of all the various factors that act simultaneously or consecutively. Likewise, attention should be given to different hazards, which will not occur at the same time, but which will nevertheless affect the protected values. Such approaches to multiple risks are important in all geographic regions susceptible to the negative impact of several types of potential hazards. In such circumstances, focusing on the impact of only one specific potential hazard could even result in higher vulnerability from another type of potential hazard.

Every risk assessment has to include potential escalations of the consequences caused by the interaction with other potential hazards (knock-on effects). One risk can increase when another potential hazard appears or when some other kind of event significantly alters the vulnerability of the system. The impact of each potential hazard on protected values and the consideration of their overall impact should guide any conclusions drawn regarding the impact of multi-risk.

On the national level, risk assessment falls under the purview of the Ministry of Interior, specifically the Risk Assessment Directorate within the Sector for Emergency Management. The Law on Disaster Risk Reduction and Emergency Management focuses on the processes and methods of the state-level action to reduce all disaster risks through risk assessments and mappings of risk in the stages of prevention, preparation, and planning, which are implemented within the wider context of disaster risk management. This law is based on an approach that involves identification, analysis, assessment, and treatment of risks that can occur due to natural or technical and technological accidents. Special emphasis in the law is given to prevention through developing a disaster risk reduction plan, creating a unifying risk registry, and establishing zones of immediate disaster risk.

#### 4. RISK ASSESSMENT IN THE EU – A GUIDELINE FOR RISK ASSESSMENT AND MAPPING OF DISASTER MANAGEMENT GUIDELINE

On 23 February 2009, the European Commission adopted the Communication: A Community approach on the prevention of natural and man-made disasters, which sets a general framework for disaster prevention and proposal of measures to minimize the impact of disasters. The Communication supports the development of EU and national policies that uphold the disaster management cycle: prevention; preparedness, response; and recovery.

The Council's conclusions about the Community's framework on disaster prevention in the EU, which were made official on 30 November 2009, highlighted that risk and hazard identification and analysis, impact analysis, risk assessment and risk matrices, development scenarios, risk management measures, and regular inspections constitute the main components EU frameworks for disaster prevention and prevention policies on all levels of government. The Council's conclusions included the invitation to the Commission to develop EU guidelines by 2010 in conjunction with the member states, while taking into account the national efforts regarding the methods of risk and hazard mapping, assessment, and analysis, all for the purpose of facilitating such efforts in the member states.

In late 2011, the Council's conclusions also invited the member states to further develop their national risk management approaches and procedures, including risk analyses, which cover potentially major natural and man-made disasters, while considering the future effect

of climate change. These guidelines are focused on national risk assessment processes and methods and on risk mapping in the prevention, preparedness, and planning stages as they unfold within the wider framework of disaster risk management. The guidelines are based on a multi-hazard and multi-risk approach.

For the purpose of these guidelines, the international standards developed by the International Organization for Standardization, in particular ISO 31000 [13], ISO 31010 [14], and the corresponding ISO Guide 73 [12], defined the terms given below.

Thus, *hazard* is “a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage” [20].

*Exposure* refers to “people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses” [20].

*Resilience* is “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” [20].

*Risk* is “a combination of the consequences of an event and the associated likelihood of occurrence” [14]. *Risk assessment* is the “overall process of risk identification, risk analysis, and risk evaluation” [14]. *Risk identification* is the “process of finding, recognizing and describing risks” [14]. *Risk analysis* is the “process to comprehend the nature of risk and to determine the level of risk” [14]. *Risk evaluation* is the “process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable” [14]. *Consequences* are the negative effects of a disaster in terms of their human, economic, environmental, and socio-political impact [14].

A *threat* is a potentially damaging physical event, phenomenon, or human activity of deliberate/malicious nature.

*Individual risk assessment* determines individual risk (i.e. probability and consequences) of a single specific hazard (e.g. a deluge) or a single specific type of hazard (e.g. floods), which occurs in a given geographic area during a given period of time.

*Multi-risk assessment* determines the overall risk from several hazards, whether they occur concurrently or consecutively, as they are interdependent, or are caused by the same triggering event or hazard, and whether they threaten the same elements at risk (vulnerable/exposed elements) without chronological coincidence.

A *hazard map* is a map that shows the degree of probability of hazard occurrence in a geographic area. Such maps can focus on only one hazard or on multiple hazards (multi-hazard map). A *multi-hazard map* is a map that shows the degree of probability of multiple hazards occurring in a geographic area.

A *risk map* is a map that shows the level of risk in a geographic area. Such maps can focus on only one risk or on multiple risks. A *risk scenario* is the representation of one risk or a multi-risk state that causes significant impacts, which are selected for the purpose of a detailed assessment of the given risk/risks, or it is an informative example or illustration of the risk/risks.

#### 4.1. Individual or multi-risk assessments

Individual risk assessments determine individual risk (i.e. probability and consequence) from one specific hazard (e.g. flood) or one specific type of hazard (e.g. flooding) occurring in a given geographic area during a given period of time.

Multi-risk assessments determine the overall risk from several hazards, taking into account the possible interactions between hazard and vulnerability if they:

1. Occur concurrently or consecutively, as they are interdependent, or because they are caused by the same triggering event or hazard;
2. Threaten the same elements at risk (vulnerable/exposed elements) without chronological coincidence.

Concurrent hazards are also called subsequent events, triggered effects, the domino effect, or cascading events, for example a rock-fall caused by a flood caused by a rainstorm or industrial accidents that pollute the environment, which in turn causes health issues. Any hazard can cause more subsequent hazards, all of which can be considered individually. The probability of each event naturally correlates with the probability of occurrence of a subsequent event or a previous triggering event. Consequence assessment then needs to consider the cumulative impact of all the different concurrent or consecutive influences.

In cases when a different risk does not occur simultaneously but still affects the same elements at risk (or threatened elements, exposed elements, causes), usually people, economic activity, the environment, and cultural, political, or social assets, risk assessment helps us understand, for instance, that a building has to be resilient to both earthquakes and floods, and that it can be at risk from both hazards.

Such approaches to multi-risk are important in all geographic regions that are vulnerable to multiple types of hazard, as is the case with many EU regions. Under these circumstances, the sole focus on the impact of only one specific hazard could increase the vulnerability to other types of hazards. For example, if the construction of a building is approved for an area susceptible to flooding, this can also make the building especially vulnerable to the effects of seismic waves of an earthquake, because its structure will contain an elevated and unnaturally positioned ground floor.

#### 4.2. Multi-risk assessments

The challenge of multi-risk assessment is to properly account for the possible side-effects (also: triggered effect, domino effect, or cascade effect) among the hazards, and for the situation in which one hazard leads to one or more sequential hazards. For instance, an earthquake and cause a gas pipeline explosion, or an industrial accident can cause a forest fire. Multi-risk assessments thus consider the interdependence between several hazards and risks.

The multi-risk approach involves a multi-hazard and a multi-vulnerability perspective.

Every risk assessment should encompass the possible implications of interactions with other hazards, i.e. one risk can increase because another hazard occurs or because the other event considerably alters the vulnerability of the system.

The multi-vulnerability perspective pertains to different exposed/vulnerable targets, for example people, transportation systems, infrastructure, buildings, cultural heritage, etc., which exhibit different types of vulnerability from various hazards and require different capacities to prevent or deal with the hazards.

Many analyses of the so-called individual risks probably consider different origins of a specific hazard up to varying degrees of complexity. However, they can often end due to an

absence of contraction of various hazards, such as different natural or man-made disasters, or combinations of the two.

There are numerous difficulties in combining the analyses of individual risks into a more integrated multi-risk analysis, including the fact that the available data for different individual risks pertain to e.g. different time intervals or different types of impact, which makes comparisons and rankings difficult and even impossible.

## 5. CONCLUSION

Risks from natural disasters involve potential losses of human life and property, and environmental damage. To reduce natural disaster risk, it is necessary to take action in keeping with adequate risk management. The priority action in risk management is to assess the risks in a given area and to plan measures for a timely response before, during, and after a natural disaster. Risk assessment is the foundation for decision making, planning, and development of at-risk areas in accordance with individual and multi-risk assessments. When several hazards occur at the same time, they can cause a cascade effect, which is very important for a multi-hazard risk assessment. Simultaneous multi-hazard risks require a comprehensive analysis and description of risks to which the population of a given area is exposed. In case of natural disaster risks, the first step is the analysis of each individual risk, and the results are presented as special risks, risks to human life, and economic risks for every process, where they are subsequently integrated into a unifying risk map, which is the basis for the planning of efficient countermeasures.

With regard to legal treatment of risk assessment in Serbia, significant efforts have been made by the adoption of a new Law on Disaster Risk Reduction and Emergency Management, which is based on the approach that involves identification, analysis, assessment, and treatment of risks that can occur due to natural or technical and technological accidents. The law particularly focuses on prevention through developing a disaster risk reduction plan, creating a unifying risk registry, and establishing zones of immediate disaster risk. The disaster risk reduction plan will enable the planning of infrastructural capital projects aimed at improving the protective infrastructure and of other measures that will reduce or eliminate a risk. The planning will be based on the treatment of unacceptable risk to be defined by the risk assessment.

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## UPRAVLJENJE RIZICIMA U KONTEKSTU PROCENE MULTIRIZIKA

*Kraj 20 i početak 21. veka obeleženi su naglim i brzim promenama: slobodnom protoku ljudi, informacija i trgovine, uzajamnim povezivanjem, ali pre svega napretkom nauke i tehnologije. Takođe dolazi i do povezivanja različitih naučnih disciplina, koje do skoro nisu imale međusobno uočljive veze, pa se javljaju multidisciplinarnе nauke. Nažalost, 21. vek donosi sve veći broj prirodnih katastrofa. Prema izveštaju o prirodnim katastrofama u Ujedinjenim nacijama EM-DAT (Emergency Events Database 2015), gubitaka i efekata izazvanih ovim katastrofama je sve više. Stoga procena rizika postaje prioritetna akcija za smanjenje rizika od prirodnih katastrofa. Procena rizika je suština upravljanja rizikom. Kao i kod povezanosti različitih naučnih disciplina i kod pojava katastrofa uočava se njihova povezanost, pa se samim tim danas sve više govori o multiriziku. Procena rizika od više opasnosti je ključni korak integrisanog upravljanja rizikom. Na globalnom i evropskom nivou, interesovanje za procenu višestrukog rizika (multirizika) se povećalo u poslednjoj deceniji.*

Ključne reči: prirodne katastrofe, rizik, procena rizika, multirizik