HOLISTIC AND MULTIFACTORIAL METHODOLOGY FOR NATURAL DISASTER RISK ASSESMENT

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Keywords: *risk assessment, multifactorial methodology, natural hazards and disaster*

Abstract: *Recent disasters dramatically affected millions of people, with hundreds of thousands of lives and US$ 1.5 trillion lost between 2005 and 2014 alone, a tenfold increase over the previous decade. Global economic loss from disasters varies on average from US$ 250 billion to US$ 300 billion each year.*

Changing climate, rapid urbanization, ongoing violence and conflicts in many parts of the world, changing demographics, technological innovations, increasing inequality and many other known and emerging changes with their inherent uncertainties have created an unprecedented context for disaster impact.

The present report presents holistic and multifactorial methodology for natural disaster risk assessment.

ХОЛИСТИЧЕН МУЛТИФАКТОРЕН МОДЕЛ ЗА ОЦЕНКА НА РИСКА ОТ ПРИРОДНИ БЕДСТВИЯ

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Ключови думи: *оценка на риска, мултифакторен анализ, природни бедствия*

Резюме: *През последните години редица бедствени явления засегнаха милиони хора, като жертвите достигнаха няколско стотин хиляди, а 1,5 трилиона долара са нанесените щети само между 2005 и 2014 г., което е десетократно увеличение в равнение с предходното десетилетие. Глобалните икономически загуби от бедствия варират средно от 250 милиарда до 300 милиарда долара всяка година.*

Промяната на климата, бързата урбанизация, продължаващото насилие и конфликти в много части на света, демографските промени, технологичните иновации, увеличаването на неравенството, нововъзникващи промени и много други фактори, налагат нов холистичен подход за оценка на риска и въздействие върху бедствията

Настоящият доклад разглежда цялостна, холистична и многофакторна методология за оценка на риска от природни бедствия.

Introduction

The risk assessment (analysis) of natural hazards is a disaster preparedness activity including pre-disaster risk reduction phase of the risk management process. Risk analysis is a base for decision making and the main tool for the risk management and scenarios development about the risk reduction. UN terms and definition are accepted and approved among risk management specialists. According that, risk assessment includes three main activities shown on fig.1: vulnerability, hazard and coping capacity assessment.

Risk – the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disruption or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. The term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period. The first definition is given by (Blaikie et al., 1994)

Risk = Hazard potential x Vulnerability
Or
Risk = Hazard x Vulnerability / Coping capacity (UNISDR, 2002; UNDP, 2004)

It must be mentioned that these are not algebraic equations and only show the interactions between risk, hazard and vulnerability.

Hazard potential is characterized by its probability (frequency) and intensity (magnitude or severity).

Vulnerability – the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

Vulnerability is determined by the potential of a community to react and withstand a disaster, e.g. its emergency facilities, disaster organization structure, education rate, early warning system, etc (coping capacity).

The coping capacity expresses the suitability of the society to "stand against disaster" and is described by the interaction of technical, organization, social and economic factors.

Methodology

There are many models and methods for disaster and damage assessment caused by particular natural hazards. Each methods or model for his own specific features. The differences in models very often lead to some disadvantages like: different results, different scenarios with various initial and final data and results, incompatibility, inappropriateness, etc. That's why during the last years the efforts are directed to search complex methods including all factors and parameters concerning risk assessment and analysis.

Basic methods and methodologies about the risk and multi-risk assessment are developed by: United nations programs (UN) – ISDR, UNDP; Inter-American Development Bank and Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ); ESPON 3.1.3 Project; Joint Research Centre (JRC), EC

IABD use four risk factors (IADB/GTZ, 2003): hazards, exposure, vulnerability and coping capacity and it is described in detail in Frantzova, 2014.

The main components (called risk factors) values are determined as follows:

$$H = w(H1) \times H1 + w(H2) \times H2 + w(H3) \times H3 + \ldots + w(Hn) \times Hn$$
$$E = w(E1) \times E1 + w(E2) \times E2 + w(E3) \times E3 + \ldots + w(En) \times En$$
$$V = w(V1) \times V1 + w(V2) \times V2 + w(V3) \times V3 + \ldots + w(Vn) \times Vn$$
$$C = w(C1) \times C1 + w(C2) \times C2 + w(C3) \times C3 + \ldots + w(Cn) \times Cn$$

where H, E, V and C are the values of the Hazard, Exposure, Vulnerability and Capacity & Measures, respectively; H1,H2…E1,E2…V1, V2….C1,C2….refer to the scaled values of the indicators; and w_i are the weights. A total sum of the weighting coefficients must be equal to 100.

The risk profile for the given selected area is expressed as:

$$R = (wH + wE + wV) - wC$$

where R is the overall risk index, H, E, V and C are the factors value of the hazard, exposure, vulnerability and coping capacity, respectively and w_i is the weighting coefficient.

The new developed and adapted methodology for risk and multi-risk assessment includes:

- Risk perception as a part of the risk assessment.

This is an attempt to quantify psychological factor as a source of increasing risk and vulnerability. Considering the models and research, risk perception can be accepted as a root foundation related to the risk management. Therefore, the inclusion in the risk assessment is imperative. The psychological variable "It won't happen to me" (Fig. 2) is associated with personal decisions. But the analogous psychological factors are the base of the human behavior and decisions. Risk perception as a key factor may be becomes the main reason for maximize vulnerability or respectively its reduction.

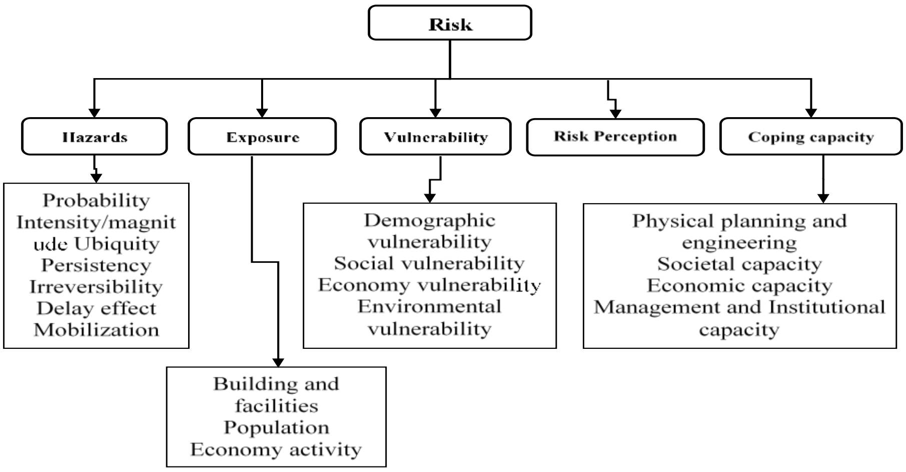
Thereby, the risk profile for the given selected area is expressed as:

$$R = wH + wE + wV + wRP - wC$$

where H, E, V, C and PR are the values of the Hazard, Exposure, Vulnerability, Coping Capacity and Risk Perception, respectively; H1, H2…E1, E2…V1, V2….C1, C2….refer to the scaled values of the indicators; and w_i are the weights.

The main feature of the methodology is the acceptance that the coefficient w is not equal to the five factors; it is assumed that various factors have varying weight and contribute in changing magnitude for the assessment of the risk levels. The values of weighting coefficients are defined similar as it is presumed that all risk factors contribute equally to the increasing or reducing of given risk. For the time being there are no scientific studies or technical methods which are able to defined whether the factor "hazard" is more important than the factor "vulnerability" or “copping capacity”. The risk factors are closely related to environment and the areas to be considered and thus their impact can range from minimum to maximum.

Thus, we can accept the "risk perception" as the one of the core factors with the highest „weight" in the establishment of the risk profile for the given phenomenon. The statement „It won’t happen to me” lead to „I won’t take any measures because it merely won’t happen to me."



- Five classification characteristics associated with risk perception.

These evaluation elements are derived from risk perception research. They have already been proposed as criteria for risk evaluation procedures in a number of countries such as Denmark, the Netherlands and Switzerland (WGBU, 1996). The following are particularly important:

- Ubiquity - Spatial distribution of damage or of damage potential.
- Persistency - Temporal scope of damage or damage potential.
- Irreversibility - Non-restorability of the state that prevailed prior to occurrence of damage. In the environmental context, this is primarily a matter of the restorability of processes of dynamic change (such as reforestation or water treatment), not of the individual restoration of an original state (such as preserving an individual tree or extirpating non-native plant and animal species).
- Delay effect - The possibility that there is large latency between the cause and its consequential damage. Latency can be of physical (low reaction speed), chemical or biological nature (such as in many forms of cancer or mutagenic changes). It can also result from a long chain of variables (such as cessation of the Gulf Stream due to climatic changes).
- Mobilization potential (refusal of acceptance) - The violation of individual, social or cultural interests and values that leads to a corresponding reaction on the part of those affected. Such reactions can include open protest, the withdrawal of trust in decision makers, covert acts of sabotage or other forms of resistance. Psychosomatic consequences can also be included in this category.

- Global Change Syndromes, specific to particular natural hazards for selected areas.

All syndromes must meet the following criteria, however:

- Each syndrome relates directly or indirectly to the environment; exclusive reference to core problems within the anthroposphere is not permitted.
- The syndrome should occur as a visible or virulent cross-cutting problem in many regions of the world.
- The syndrome should describe non-sustainable development and/or significant environmental degradation.

A cardinal feature of global change is that humankind itself is now an active factor within the Earth System, playing a significant role at the planetary scale. Human interventions, as manifested in the depletion of raw materials, shifts in material and energy fluxes, changes to large-scale natural structures and critical stresses on environmental assets, are altering the very character of the Earth System to an increasing degree. The complexity of the processes involved or driven by these changes poses a major challenge for the scientific community and generates a number of new research issues.

Global change research must therefore deal with the diagnosis, prediction and assessment of global trends, the prevention of negative trends, “repairing” existing damage (rehabilitation and reconstruct) and adaptation to the unavoidable. Therefore, the primary interactions between these trends must be identified, described and explained.

Such research should be guided by the principle of sustainable development. The crucial element of this concept, now generally acknowledged, is the interdependence of environment and development. This reflects a growing insight that human beings and their environment are closely integrated within a system of mutual interaction. Research on global change is therefore confronted with two fundamental problems. Firstly, the investigation of the Earth System requires an integrative approach because the interactions between its components operate across the boundaries of single disciplines, sectors or environmental media. The second fundamental problem is the enormous complexity of the dynamic interrelationships involved, which makes a distinct description, any overall analysis and modeling much more difficult. The only approach capable of responding adequately to these problems is one that is networked and interdisciplinary.

The syndrome concept provides a new basis for global change research, the knowledge base of which continues to be split up according to the environmental media or core problems. This sectoral or disciplinary approach is certainly justified: without searching for a deeper understanding of the individual problem areas and their functional mechanisms, it is impossible to understand the specific aspects of environmental stress.

Syndrome \ Core problems	Climate change	Loss of biodiversity	Soil degradation	Scarcity and pollution of freshwater	Threats to world health	Threats to food security	Population growth and distribution	Man-made disasters	Overexploitation and pollution of the world's oceans	Global disparities in development
Sahel Syndrome		•	•	•		•	•	•		•
Overexploitation Syndrome	•	•	•	•				•	•	•
Rural Exodus Syndrome		•	•			•	•	•		•
Dust Bowl Syndrome	•	•	•	•		•		•		
Katanga Syndrome		•	•	•						
Mass Tourism Syndrome		•	•	•				•		
Scorched Earth Syndrome		•	•		•	•	•			•
Aral Sea Syndrome	•	•	•	•			•	•		•
Green Revolution Syndrome		•	•	•	•	•	•			•
Asian Tigers Syndrome	•	•	•	•	•		•			•
Favela Syndrome	•		•	•	•		•			•
Urban Sprawl Syndrome	•	•	•	•						
Major Accident Syndrome		•	•		•					
Smokestack Syndrome	•	•	•		•	•		•		
Waste Dumping Syndrome		•	•		•					
Contaminated Land Syndrome		•	•		•				•	

Fig. 1. Assignment of core problems of global changes to syndromes (WBGU, 1998)

Why is the risk perception so important?

The study of risk perception arose out of the observation that experts and people often disagreed about the risky various technologies and natural hazards. Three major families of theory have been developed: psychology approaches (heuristics and cognitive), anthropology/sociology approaches (cultural theory) and interdisciplinary approaches (social amplification of risk framework).The earliest psychometric research was done by psychologists Daniel Kahneman and Amos Tversky, who performed a series of gambling experiments to see how people evaluated probabilities. Their major finding was that people use a number of heuristics to evaluate information.

Research within the psychometric paradigm turned to focus on the roles of affect, emotion, believes, etc, in influencing risk perception. Melissa Finucane and Paul Slovic have been the key researchers here.

Daniel Kahneman known for his work on the psychology of judgment and decision-making, as well as behavioral economics, for which he was awarded the 2002 Nobel Memorial Prize in Economic Sciences (shared with Vernon L. Smith).

Meanwhile, many different methods, methodologies and techniques have been developed to predict with the highest accuracy relative frequencies and magnitude of natural events and possible damage.

Risk perception, by contrast is based largely on personal experience, mediated information, intuitive estimations, cultural evolution, etc. As studies of risk perception have shown that people associate risks not only with physical damage, but also violations of social and cultural values (Fischhoff et al., 1978; Covello, 1983; Slovic, 1987; Brehmer, 1987; Gould et al., 1988; Renn, 1989; Drottz-Sjöberg, 1991; Pidgeon et al., 1992; Jungermann and Slovic, 1993; Rohrmann, 1995). The technical-scientific risk perspective has largely excluded this dimension of risk, restricting itself essentially to damage to property, health and the environment (WGBU). It was only psychological and sociological risk research that then created a basis for sufficiently characterizing and largely explaining societal risk experience. Besides underscoring non-physical risk dimensions, perception research has also shown that people base their evaluations of risks on a series of contextual risk properties in addition to the probability and severity of damage.

On the basis of the knowledge of non-physical dimensions and contextual risk properties we can understand the human behavior against natural events and threats. What a society defines or professes to perceive as risk is thus not necessarily in any direct relation to the magnitude of risk as defined by the two components of probability of occurrence and extent of damage. (Slovak, 2000; Slovak, 2002; Fischoff at all, 2002; Renn, 1998).

It is very important for several reasons that a proactive and rationally structured risk policy addresses the issue of risk perception. For one thing, the behavior of people is guided by their perceptions and not by scientific risk models. The perception of risk is not independent of the 'objective' risk. Over the long run, only those risk perceptions will prevail that tally with the experience of real damage. However, in rare cases, imagined risks can generate precisely those symptoms that are in principle caused by the damage potentials of the risk sources in question. Psychosomatic reactions are frequently the consequences of risk perceptions (Aurand and Hazard, 1992).

Secondly, in addition to severity and probability people also act on other risk properties that not only reflect their personal preferences but should also be integrated in a rational risk policy on the basis of normative considerations (Renn, 1998). Whether a potential damage is irreversible or not, or whether it may impact upon other people or upon future generations, are dimensions that are usually excluded from classic risk assessments.

Thirdly, most people are not indifferent to distributional patterns of damage over time and space. The risk assessment process is based by definition on relative frequencies, necessarily meaning that averages are formed over space and time. However, in the perception of most people it is by no means the same thing whether a source of risk damages 1,000 people at one blow or continuously damages 1,000 people over a certain period (Jungermann and Slovic, 1993).

Moreover, people also link concepts of social equity and justice to distributional patterns. In most cultures, an asymmetrical distribution of benefits and risks requires a particular social justification. Whether a risk is viewed as fair or acceptable depends less upon the magnitude of the risk than upon an individual or cultural standard of equity. Classic risk assessments do not inform us on this point (WGBU,1998).

Validation of complex risk assessment methodology

Multifactorial methodology is validated via a former disastrous even. Forest fire in the area of Etropole, October 2010 in Stara Planina Mountain has been selected.

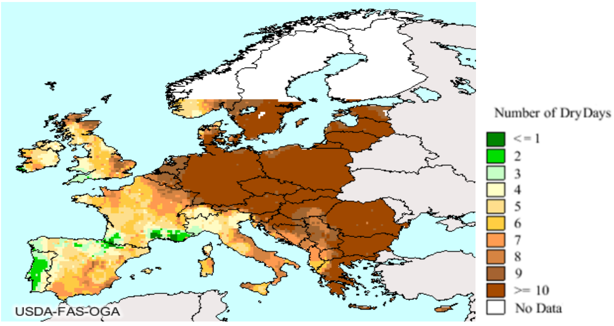
According to data of the Ministry of Interior, on November 10, 37 fires was burning on the territory of the country. The most severe forest fires are located in the Stara Planina, Lovech region.

One of the heaviest fires in Stara Planina Mountain, emerged on November 6, 2010 in a difficult accessible, highly intersected area, near the villages of Yamna, Patno Bardo, Duckot, Zarbavica. The situation is further complicated due to high air temperature, strong winds in the area of fire and the very low soil humidity. The fire was suppressed on 10.11.2011 using aviation equipment.

Meteorological parameters are based on the data from United States Air Force Weather Agency (AFWA) and World Meteorological Organization (WMO).

WMO and AFWA data show a lack of rainfall, very low soil humidity and high level of drought. The state of the environment can be described with high volume of the fuel materials (predominantly grass, shrub and wood materials) with high density due to the autumn fall.

Based on the analysis of the available data (not specified here), we can conclude that under existing conditions, the degree of fire hazard is significantly high for the given area.



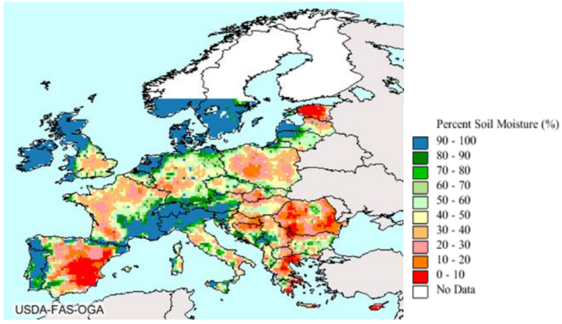
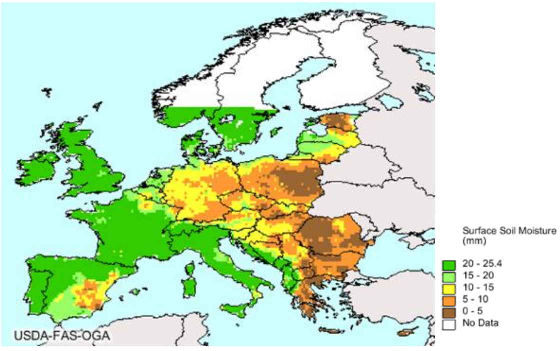


Fig. 2. Number of dry days from 1 to 10/10/10 (AFWA) (AFWA//LIS)

Fig. 3. Soil moisture 11/01/11 to 11/10/11



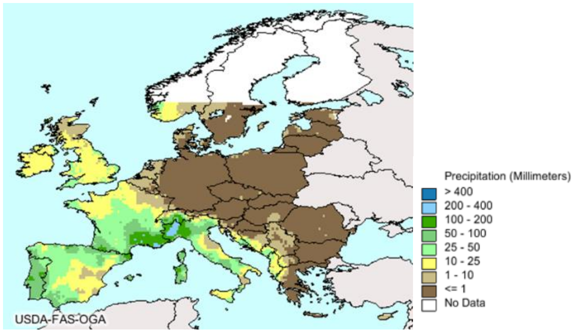


Fig. 4. Soil moisture from /01/11 to 11/10/11 (AFWA)

Fig. 5. Precipitation from 11/01/11 to 11/10/11 (AFWA)

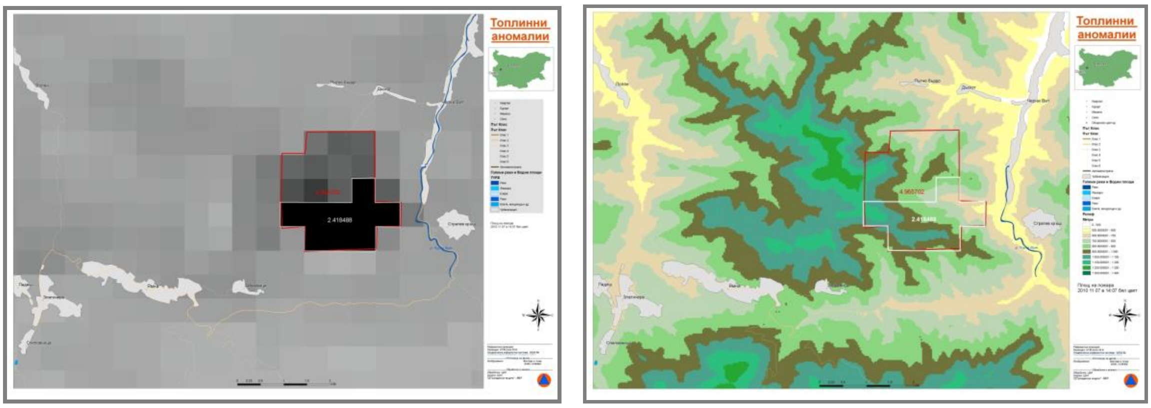


Fig. 6. Forest fire area - Etropole, October 2010, Stara Planina Mountain (2,418 km^2)
(The maps are prepared in the former DG Civil Protection, MoI)

Risk assessment is based on: 4 indicators for hazard; indicators for exposure; 19 indicators for vulnerability; 19 indicators for coping capacity and risk perception conception.

These values are divided into five risk classes and described the risk levels – the data falls in the interval between 0 and 56.25.

Risk levels	Very low	Low	Medium	High	Very high
Value	0-11.25	11.25-22.50	22.50-33.75	33.75-45	45-56.25

Calculated results with value 19.5 (34.67 %) show low risk profile for the given selected area which is consistent with the real situation.

Conclusions

The main conclusions are related to the adaptation and use of the developed holistic methodology about risk assessment.

The adaptation is focused to the clarification and selection of the risk factors, weighting coefficients assessment and sensitive analysis

The application of the developed methodology to the forest fire in the area of Etropole, October 2010 in Stara Planina Mountain shows reasonable results and considerations.

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