INTEGRATED VULNERABILITY ANALYSIS

FOR DISASTERS RISK REDUCTION

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ABSTRACT

Vulnerability is a key element in the risk conception (risk = hazard + vulnerability), representing the circumstances determined by 'physical, social, economic, and ecologic factors or processes, of a community, system or asset that make it susceptible to the damaging effects of a hazard' [11]. A crucial part of the policies for disaster risk reduction is the reduction of vulnerability, which is related to the susceptibility of human development: human life, economy, social organisation, and the physical aspects of the environment. Although public and economic vulnerability are perceived as the most important components of vulnerability, it is very important to take into account the significance of the biophysical basis for human life - the environmental and physical aspects of vulnerability and to deal with them in an integrated way.

The publication aims at analysis of the integrated vulnerability as a tool for disaster risk reduction by reduction of the vulnerability itself. The publication presents the approaches for integrated vulnerability analysis. The vulnerability is integrally analysed by its factors (exposure, susceptibility and resilience) and dimensions (social, economic, environmental and physical). The integrated vulnerability of a territory is measured as a combination of the factors listed above. All of them can be represented by a set of indicators, whose selection should be reasonable and well-grounded. The set of indicators should allow measurement of the vulnerability factors for each of the vulnerability dimensions. An integrated vulnerability analysis is developed and presented for a case study from Republic of Bulgaria.

Key words: integrated vulnerability analysis, disaster risk reduction, Republic of Bulgaria

INTRODUCTION

Natural hazards are nothing new to humanity. Floods, droughts, earthquakes, and others have accompanied human development from its beginning. That is why disaster risk reduction and enhancement of social sustainability remain key challenges for both developing and developed countries. The main reason for that is the growing exposure of humans and their assets in risk areas on the one hand, and on the other, the increased frequency of extreme natural events due to climate change.

Scientists agree that the reduction of the natural hazards and threats to human security cannot be achieved by putting efforts solely in natural hazards mitigation. Societies have to continue living with the changing environment, thus they need to enhance sustainability by reduction of their vulnerability to natural hazards as well. The first step in this process is to measure vulnerability at different territorial levels and its spatial and temporal

characteristics. Therefore, the aim of the current publication is to present an overall approach for measurement of integrated vulnerability at different administrative territorial levels as a tool for disaster risk reduction in Bulgaria.

Vulnerability is a key element of the risk conception (risk = hazard + vulnerability), representing the circumstances determined by 'physical, social, economic, and ecologic factors or processes, of a community, system or asset that make it susceptible to the damaging effects of a hazard' [11] UN-ISDR. A crucial part of the policies for disaster risk reduction is the reduction of vulnerability, which is related to the susceptibility of human development: human life, economy, social organisation, and the physical environmental aspects. Although public and economic vulnerability are perceived as the most important components of vulnerability, it is very important to take into account the significance of the biophysical basis for human life - the environmental and physical aspects of vulnerability, and to deal with them in an integrated way. The ability to measure vulnerability is increasingly being seen as a key step towards effective risk reduction and the promotion of a culture of disaster resilience. In the light of increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is a crucial task if science is to help support the transition to a more sustainable world [8] Kasperson et al.

THEORETICAL BACKGROUND
The vulnerability concept - theoretical and conceptual issues
Four main approaches are related to the conceptualisation and measurement of risk and its components – hazard and vulnerability. The Political Economy Approach is illustrated with the so called Pressure and Release (PAR) model [2] Blaikie at al. and [12] Wisner et al., and the related Sustainable Livelihood Framework [3] DFID. This framework presents the organizational, institutional and political methods supporting local capacity building for natural disasters risk reduction, and shows that these structures are reproduced by the actions of individuals and households. The Social – Ecological Approach underlines the necessity to put human - environmental systems in the centre of risk assessment. This approach is presented by [10] Turner et al. where the transforming abilities of the society with regards to natural circumstances are shown, as well as the effects of the changing environment on social-economic systems. The framework also stresses that the vulnerability elements – exposure and susceptibility of a certain system (individuals, communities, etc.) can be rationally understood only if we address these related approaches. The third approach is connected with Disaster Risk Management (DRM) and aims at development of an integrated interpretation of risk. The approach divides vulnerability into its component: exposure, susceptibility and societal-response capacities or lack of resilience. The approach perceives vulnerability as intrinsically dynamic and, therefore, its assessment should not be restrained only to identification of the system's shortcomings but also consider its potential feedback and intervention instruments (existing and potentially developed) for reduction of the system's vulnerability. This approach also involves the sustainable development perspective of vulnerability assessment. The approach of Climate Change Adaptation (CCA) is based on the IPCC's definition that vulnerability is a function of exposure, susceptibility and adaptive capacities [7] IPCC. This approach takes into account the rate and magnitude of climate change. Particularly, the magnitude and frequency of the potentially hazardous

natural phenomena are included when calculating the vulnerability to climate changes. Thus, the vulnerability concept changes into a definition of risk.

The current research adopts the recently developed holistic approach for disaster risk assessment and management, and the 'MOVE' conceptual framework (figure 1).
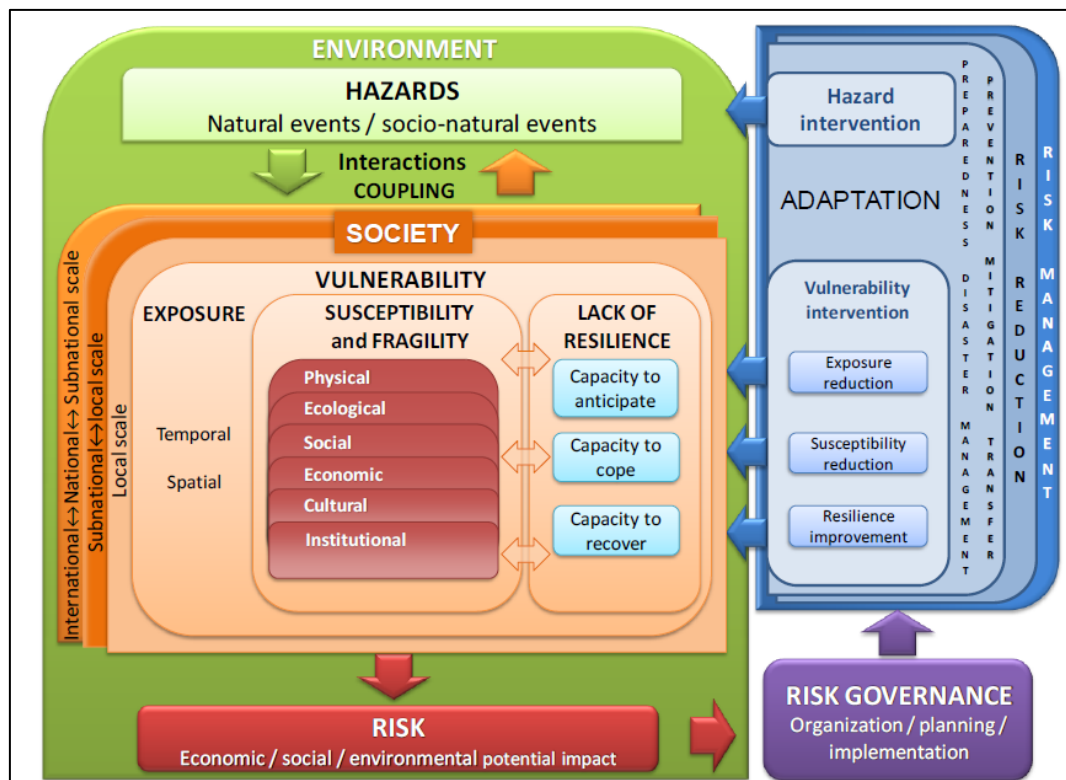

Figure 1. The 'MOVE' conceptual framework - a holistic approach to disaster risk assessment and management [4] European Commission.

This conceptual framework was developed within the 'MOVE' project (www.move-np7.eu) and joins the concepts of risk and risk management[3]. The first concept presents risk as the result of the societies' exposure to hazards in time and space and their vulnerability. The hazards are presented as natural or socio-natural events, which are a combination of society and environment. Risk management and adaptation aim to modify the initial vulnerability conditions or hazards. Vulnerability is a combined result of the exposure, susceptibility (fragility) and resilience (capacity to anticipate, cope and recover).

$$Vulnerability = Exposure^4 + Susceptibility^5 - Resilience^6 \qquad (1)$$

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[3] The term Disaster Risk management (DRM) also encompasses the concept of Disaster Risk Reduction (DRR). Thus these terms are used almost synonymously. A/N

[4] Exposure is defined as the predisposition of a system to be disrupted by a hazardous event due to its location in the same area of influence [5] Florina.

[5] Susceptibility will be defined as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous events. A/N

[6] The lack of resilience is another important vulnerability factor that reflects the capacity level of a society to anticipate (to intervene proactively the risk conditions), to adapt (to be prepared to face future hazardous events), as well to cope and recover effectively when such events occur. A lack of these capacities increases the vulnerability of the society. A/N

Hazard and vulnerability trigger risk, which is the potential impact of the hazard occurrence on economic, social and environmental dimensions of society. The degree of risk will depend both on the susceptibility (or fragility) and the lack of resilience of the society (and of the environment, in some cases), as well as how they are related to the exposure (from local to national and international scales). In addition to the key factors which determine vulnerability, the following core vulnerability dimensions can be addressed within the comprehensive holistic assessment process:

- ✓ The *social dimension (component)* represents the tendency of human welfare to be damaged by disruption of the individual (physical and psychological health) and collective (healthcare, education, services, etc.) social system and its characteristics (gender, marginalisation of social groups, etc.);
- ✓ The *economical dimension (component)* represents the tendency for economic loss from destruction of physical assets and/or disruption of the production processes;
- ✓ The *environmental dimension (component)* represents the potential for destruction of all ecological and biophysical systems and their functions. This component involves basically all ecosystem functions and services [9] Renaud.

Vulnerability assessment

In recent years, an increasing number of global and local initiatives have been launched to measure risk and vulnerability with a set of indicators and indices [1] Birkmann. In general, indicators are management tools which describe and operationalise complex system characteristics in a quantitative and transparent way. Therefore, indicator frameworks tend to bridge the gap between theoretical concepts of complex systems and decision making [6] Gallopin. This enables a comparative analysis, benchmarking and support to decision makers in complex decision situations (e.g. in crisis management and emergency planning).

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Indicators for the three vulnerability dimensions (Exposure, Susceptibility, and Resilience) are developed in compliance with the adopted vulnerability conceptual framework. The indicators are bound to the particular vulnerability dimensions (Social, Economic, and Environmental) (see table 1).

Table 1. Relationship between vulnerability dimensions and factors

Vulnerability	Exposure	Geograph-ic scale	Susceptibility	Geographic scale	Resilience	Geograph-ic scale
Social Component	Population density	L, R,N	Education	L, R,N	Transport infrastructure	L, R,N
	Urbanized territory	L, R, N	Communication penetration rate	L, R, N	Warning system	L, R, N
	Population structure	L, R, N	Health services	L, R, N	Institutional capacity	L, R, N
		L, R, N	Human health	L, R, N	Emergency service	L, R, N
Economic component	Land use	L, R, N	Economic development	L, R, N	Amount of investment	L, R, N

Vulnerability	Exposure	Geograph-ic scale	Susceptibility	Geographic scale	Resilience	Geograph-ic scale
Environmental component	Ecosystem services	L, R, N	Protected natural areas	L, R, N	Amount of investment	L, R, N

Key: L- Local level; R- Regional level; N- National level.

The table is elaborated by the authors

Exposure indicators explain how social entities, such as individuals, households, organizations, communities (Social dimensions), or economic activities, i.e. industries, agriculture, etc. (Economic dimensions), or environment (Environmental dimensions) are exposed to hazardous events. *Susceptibility* considers the indicators which evaluate the sensitivity of an element at risk (Social system, Economic system and Environment) before and during a hazardous event. They can be evaluated through levels of preparedness, education, income, communication penetration rate, trust in institutions, etc. *Resilience* indicators clarify the ability of a system to persist if exposed to a perturbation by recovering during and after the hazardous event. The indicators used are warning system, evacuation routes, institutional capacity, emergency service, etc. the description of sub-indicators, as well as their connection with vulnerability are presented in table 2.

Table 2. Description of natural disasters vulnerability indicators

Name of the indicator	Dimensions of vulnerability	Definition of sub -indicator	Units	Functional relationship with vulnerability
Exposure				
Population density	S	Provides information on the number of people per unit of area.	people/km^2	Higher number of people, higher vulnerability
Urbanised territory	S	Relative share of the area which is urbanized	%	Higher %, higher vulnerability
Old people	S	Relative share of the population at 65 years and more	%	Higher %, higher vulnerability
Disabled people	S	Population at 16 and more years with long-term reduced ability to work or degree of disability (from 50 to 90%)	%	Higher %, higher vulnerability
Land use	Ec	Area used for industry, agriculture, any types of economic activity	%	Higher %, higher vulnerability
Ecosystem services	En	Total value of the assessed ecosystem services, including: ecological integrity, provisioning services, regulating services, and cultural services (B. Burkhard, F. Kroll, F. Müller & W. Windhorst et al. 2009)	value	Higher value, higher vulnerability
Susceptibility				
Education	S	Population at 7 and more years with high education (high and higher)	%	Higher %, lower vulnerability
Hospitals	S	Number of beds in treatment hospital facilities per 10000 people	number	Higher %, lower vulnerability
Human health	S	Population per 1 doctor	number	Higher number, higher vulnerability

Communication penetration rate	S	Relative share of occupied dwellings with Internet access	%	Higher %, lower vulnerability
GDP per capita	Ec	Measures the standard of living in the region and the degree of development of the local economy. The higher GDP per capita the region has, the stronger is the local economy and the better the standard of living of the local population are.	value	Higher value, lower vulnerability
Protected natural areas	En	Protected zones under Art. 6 of the BDA as part of the European ecologic network 'NATURA 2000' for protection of types of natural habitats under Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora and for the protection of wild birds habitats under Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds.	km^2	Higher km^2, higher vulnerability
Number of species	En	Number of bird species, reported to the EC for the period 2007 – 2012 with regards to Directive 92/43/EEC	number	Higher number, higher vulnerability
Resilience				
Road network per 1000 km^2— km	S	Total length of highways and roads in the region. The republican road network is of crucial importance for the transportation of passengers and loads around the country. The indicator does not include streets in settlements.	km	Higher km, lower vulnerability
Acquired tangible fixed assets	Ec	Acquired long-term direct material assets by construction (after putting in operation) and purchase.	value	Higher value, lower vulnerability
Foreign direct investments in non-financial enterprises with accumulation	Ec	Investments (transactions) in long-term relations and interests of foreign residents (direct foreign investor) in investment enterprises, established in Bulgaria.	value	Higher value, lower vulnerability
Availability of the tangible fixed assets with ecological use	En	Expenditure on acquisition of tangible and intangible fixed assets with ecological use.	value	Higher value, lower vulnerability

*The table is elaborated by the authors
**Data source: Bulgarian National Statistical Institute (www.nsi.bg)*

Calculation and mapping of integrated vulnerability index
As a first step, the system of indicators presented in table 2 is transformed in comparable units by applying values 1, 2, 3, 4 or 5 depending on the category (very low, low, medium, high or very high vulnerability). Next, since indicators have different meanings for specific hazards, a hazard-specific weight has to be found and applied. Generalised

classes of multi hazard from hydro-meteorological events are defined by the authors to be used at regional level in North Bulgaria. The set of sub-indicators are applicable at all governmental levels and the results can be compared. The weight of the vulnerability factors was calculated using the entropy method. The total weight for each separate region (municipality) for integrated exposure, susceptibility and resilience is determined according to the following formula:

$$Integrated\ Exposure_{S+Ec+En} / Susceptibility_{S+,Ec+En} / Resilience_{S+Ec+En} =$$
$$= Indicator\ Y * Weight\ of\ the\ indicator + Indicator\ Z * Weight\ of\ the\ indicator +$$
$$Indicator\ N * Weight\ of\ the\ indicator$$
$$(2)$$

The integrated vulnerability is calculated by the following correlation:
$$V_{int} = E_{int} + S_{int} - R_{int} \tag{3}$$

Thus, the calculated integrated exposure, susceptibility, resilience and vulnerability indexes are classified in five classes (Very low, Low, Medium, High and Very high) and mapped (figure 2).
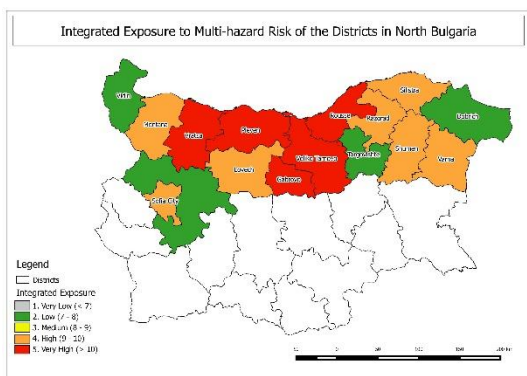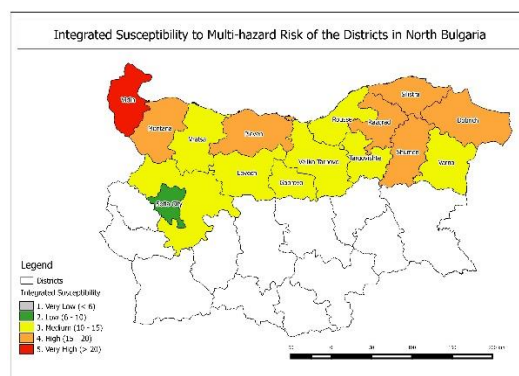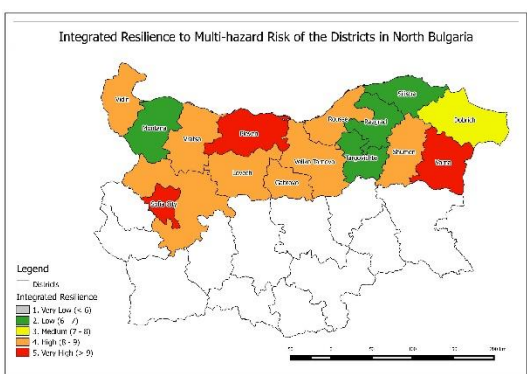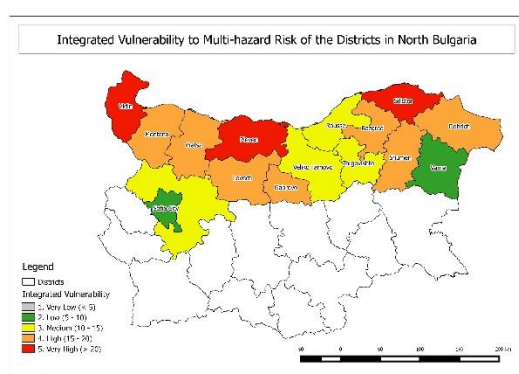

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Figure 2. Integrated exposure, susceptibility, resilience and vulnerability of the administrative districts in North Bulgaria.

* The maps are elaborated by the authors.
**Data source: Bulgarian National Statistical Institute (www.nsi.bg)

RESULTS AND DISCUSSIONS

Figure 2 visualises the spatial distribution of the integrated indices of the three vulnerability factors – exposure, susceptibility and resilience for the administrative districts in North Bulgaria. The analysis of the maps shows that: the results correspond to the reality; and that the application of an integrated and multidisciplinary approach for vulnerability assessment of natural-disaster risk accounts for the physical context, the complexity and dynamics of the social and natural systems, and their interconnectedness. The holistic approach will encourage more effective risk governance and management through the development of prevention strategies to face risks and disasters. The result of the holistic approach will help to formulate the problem and to give an answer, with associated uncertainties and approximations, but taking into account the whole aspect of risk.

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