A Fuzzy Logic Method for Assessment of Risk Management Capability

P. Zlateva, D. Velev, and L. Raeva

***Abstract*—The paper proposes a an fuzzy logic method for assessment of risk management capability. The fuzzy logic method is developed as a hierarchical system with several inputs and one output. The obtained results can support the assessment of risk management capability on Member State, either at national or the appropriate sub-national level. The proposed method for the assessment of risk management capability is envisaged to be implemented as a part of the information system for integrated risk management of natural disasters. This system can be successfully used in e-government.**

***Index Terms*—Fuzzy logic method, risk management capability, risk assessments, risk prevention and preparedness.**

I. Introduction

During the last decades the word experiences much more often the severity of natural disasters that led to losses of human lives, damages to infrastructure, housing, public services etc. and hamper the sustainable development of today`s societies. Between 1980 and 2012 around 42 million life years were lost in internationally reported disasters each year [1].

Moreover the Fukushima disaster showed that experts have to undertake new approaches for managing risks, taking into account all subsequent aspects of a certain disaster.

Now, the need to address disaster risks caused by natural hazards, taking into account risks associated with environmental, technological and anthropological hazards has been recognized. The importance of implementing the multi-risk approach as a method for effective and adequate risk management has been considered in the international agenda.

It has been acknowledged that the policies for Disaster risk reduction, Sustainable development and Climate Change Adaptation must be developed and performed simultaneously in order to ensure that all preconditions for ensuring acceptable level of sustainability are taken into account.

At an International and European level efforts have been made for the promotion of prevention measures for improvement of disaster risk management policies. "The UN General Assembly has endorsed a major shift in emphasis from disaster management to disaster risk management..:" (Margareta Wahlström, Head of the UN Office for Disaster Risk Reduction, 4 June 2015, Geneva) [2]

In order to be able to measure progress in disaster risk management there must be a regular assessment of the management capabilities.

There are many qualitative and quantitative methods for the risk management assessment [3]. However, it is necessary to point out, that the risk assessment from natural hazards is done under the subjective and uncertain conditions [4]. The fuzzy logic approach is an appropriate tool for risk management assessment. This approach provides adequate processing the expert knowledge and uncertain quantitative data [5], [6].

The aim of this paper is to propose a fuzzy logic method for assessment of *risk management capability.* The fuzzy logic method is developed as a hierarchical system with several inputs and one output. The obtained results can support the assessment of risk management capability, either at national or the appropriate sub-national level.

The proposed method for the assessment of risk management capability is envisaged to be implemented as a part of the information system for integrated risk management of natural disasters. This system can be successfully used in e-government.

II. Problem Statement

In the Decision No 1313/2013/EU of the European Parliament and of the Council on a Union Civil Protection Mechanism [7], which entered into force on 1 January 2014 the following definitions, are given:

- *Risk management capability* means the ability of a Member State or its regions to reduce, adapt to or mitigate risks (impacts and likelihood of a disaster), identified in its risk assessments to levels that are acceptable in that Member State. Risk management capability is assessed in terms of the technical, financial and administrative capacity to carry out adequate:

1) Risk assessments;
2) Risk management planning for prevention and preparedness;
3) Risk prevention and preparedness measures.

- *Disaster* means any situation which has or may have a severe impact on people, the environment, or property, including cultural heritage;
- *Response*' means any action taken upon request for assistance under the Union Mechanism in the event of an imminent disaster, or during or after a disaster, to address its immediate adverse consequences;

Manuscript received June 5, 2015; revised August 16, 2015. This work was supported in part by the Bulgarian National Science Fund for the support under the Grant No. DFNI-I02/ 15 from 2014.

P. Zlateva is with the ISER, Bulgarian Academy of Sciences, Sofia 1113, Acad. G. Bonchev str., bl. 2, Bulgaria (e-mail: plamzlateva@abv.bg).

D. Velev is with the University of National and World Economy, Sofia 1700, Bulgaria (e-mail: dgvelev@unwe.bg).

L. Raeva is with the DG Fire Safety and Civil Protection, Ministry of Interior, Sofia 1172, Bulgaria (e-mail: lkraeva.160@mvr.bg).

DOI: 10.7763/IJIMT.2015.V6.612

It is evident that the assessment of risk management capability covers the whole risk management cycle.

In Commission staff working paper "Risk Assessment and Mapping Guidelines for Disaster Management" /SEC (2010) 1626 from 21.12.2010/ [8], according to ISO/IEC 31010:2009 [9] and UNISDR 2009 (UN-International Strategy for Disaster Risk Reduction) [10] the following definitions are given:

- *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. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.
- *Natural hazard is* natural process or phenomenon 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
- *Risk* is a combination of the consequences of an event (hazard) and the associated likelihood/probability of its occurrence.
- *Risk assessment* is the overall process of risk identification, risk analysis, and risk evaluation.
- *Risk identification* is the process of finding, recognizing and describing risks.
- *Risk analysis* is the process to comprehend the nature of risk and to determine the level of risk.
- *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/are acceptable or tolerable.
- *Risk criteria* are the terms of reference against which the significance of a risk is evaluated.
- *Consequences* are the negative effects of a disaster expressed in terms of human impacts, economic and environmental impacts, and political/social impacts.
- *Human impacts* are defined as the quantitative measurement of the following factors: number of deaths, number of severely injured or ill people, and number of permanently displaced people.
- *Economic and environmental impacts* are the sum of the costs of cure or healthcare, cost of immediate or longer-term emergency measures, costs of restoration of buildings, public transport systems and infrastructure, property, cultural heritage, etc., costs of environmental restoration and other environmental costs (or environmental damage), costs of disruption of economic activity, value of insurance pay-outs, indirect costs on the economy, indirect social costs, and other direct and indirect costs, as relevant.
- *Political/social impacts* are usually rated on a semi-quantitative scale and may include categories such as public outrage and anxiety, encroachment of the territory, infringement of the international position, violation of the democratic system, and social psychological impact, impact on public order and safety, political implications, psychological implications, and damage to cultural assets, and other factors considered important which cannot be measured in single units, such as certain environmental damage.

A. Risk Management Planning

Risk management planning can be carried out per individual risk or, in an integrated cross-sectoral or even multi-risk approach [8]. The main idea during the planning is to set out how each risk can be reduced, adapted to or mitigated in terms of impacts and likelihood by implementing selected prevention and preparedness measures [11]. The planning would also need to indicate the required resources and timelines, and assign responsibilities, as appropriate. Multiple good practices are described in the EU's Climate-Adapt platform [12].

B. Risk Prevention and Preparedness Measures

The EU Civil Protection legislation was revised at the end of 2013 to ensure better response to natural and man -made disasters in a swift, preplanned and effective manner and thus to increase the safety of EU citizens and disaster victims worldwide [7]:

1) *Preparedness* means a state of readiness and capability of human and material means, structures, communities and organisations enabling them to ensure an effective rapid response to a disaster, obtained as a result of action taken in advance;
2) *Prevention* means any action aimed at reducing risks or mitigating adverse consequences of a disaster for people, the environment and property, including cultural heritage.

According [13] *Prevention* means the outright avoidance of adverse impacts of hazards and related disasters. In particular *disaster prevention* expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance.

Currently the experts of the European Commission prepare Guidelines for the Risk management capability assessment. The draft of these Guidelines includes three sections - risk assessments; risk management planning; implementing risk prevention and preparedness measures. Each section provides a set of questions, which covers the administrative, technical and financial capacities, such as the framework, coordination, expertise, stakeholders, information and communication, methodology, infrastructure, equipment and financing. The complete assessment of the risk management capability is proposed to carry out on the basis of 51 questions, which with 4 allowable levels (see Appendix) [14].

III. Description of the Fuzzy Logic Method

The idea is the proposed method for assessment of risk management capability to take into account the subjective of the expert knowledge and uncertain quantitative data in regarding the answers of the defined questions.

The method is developed on basis of fuzzy logic as a two-level hierarchical system with several inputs (in particular, 51 as the defined questions) and one output.

The first level includes three fuzzy logic subsystems. The second level includes one fuzzy logic subsystem.

The inputs of the first fuzzy logic subsystem on the first level are 16 numbers, corresponding to the defined questions from *Question 1* to *Question 16*. The indicator "*Risk assessment*" is introduced as an intermediate variable, which is considered as the first intermediate output.

The inputs of the second fuzzy logic subsystem on the first level are also 16 numbers, corresponding to the defined questions from *Question* 17 to *Question* 32. The indicator "*Risk management planning*" is an introduced as intermediate variable, which is considered as the second intermediate output.

The inputs of the third fuzzy logic subsystem on the first level are 19 numbers, corresponding to the defined questions from *Question* 33 to *Question* 51. The indicator "*Implementing risk prevention and preparedness measures*" is an introduced as intermediate variable, which is considered as the third intermediate output.

The inputs of the fuzzy logic subsystem on the second level are the three intermediate outputs of the three fuzzy logic subsystems: "*Risk assessment*", "Risk *management planning*" and "*Implementing risk prevention and preparedness measures*", respectively.

The output of the third fuzzy logic subsystem is the output of the whole fuzzy logic system. In particular, it is the variable "*Assessment of risk management capability*".

The value of this output variable is a criterion for the risk management capability about the ability of a regional government authorities to reduce, adapt to or mitigate risks (impacts and likelihood of a disaster), identified in its risk assessments to levels that are acceptable. The higher value corresponds to the higher risk management capability.

In this study, the all input and output variables are considered as linguistic variables. Their values depend on quality and uncertainty of the available information that may result from measures, historical analysis, subjective testimonies, possibly conflicting, and assessments done by the experts themselves.

The basic fuzzy sets and subsets for the input and output linguistic variables are introduced and they are described in natural language, as follow:

- Input variable Q ("*Question answer level*")

Complete set of input variable "*Question answer level*", Q is divided into five subsets, representing by five fuzzy membership functions:

VS - subset "*Very small question answer level*";
S - subset "*Small question answer level*";
M - subset "*Middle question answer level*";
B - subset "*Big question answer level*";
VB - subset "*Very big question answer level*".

It is assumed that the all elements of set Q accept values in the interval [0, 4].

- Intermediate variable R ("*Risk assessment*", "*Risk management planning*", "*Implementing risk prevention and preparedness measures*")

Complete set of "*Intermediate variable level" of R* is divided into five subsets, representing by five fuzzy membership functions:

R_1 or *VS* - subset "*Very small level of the intermediate variable*";

R_2 or *S* - subset "*Small level of the intermediate variable*";

R_3 or *M* - subset "*Middle level of the intermediate variable*";

R_4 or *B* - subset "*Big level of the intermediate variable*";

R_5 or *VB* - subset "*Very big level of the intermediate variable*".

It is assumed that the all elements of set accept values in the interval [0, 10].

- Output variable A (*Assessment of risk management capability*)

Complete set of output variable "*Assessment of risk management capability*", A is divided into five subsets, representing by five fuzzy membership functions:

A_1 or *VS* - subset "*Very small assessment of risk management capability*";

A_2 or *S* - subset "*Small assessment of risk management capability*";

A_3 or *M* - subset "*Middle assessment of risk management capability*";

A_4 or *B* - subset "*Big assessment of risk management capability*";

A_5 or *VB* - subset "*Very big assessment of risk management capability*".

It is assumed that the all elements of set accept values in the interval [0, 100].

The all input and output variables are considered as linguistic variables with trapezoid membership functions.

In general, the degree of importance λ_i (weight coefficient) of corresponding input variables for fuzzy logic inference are different. They are assigned to each input variable *i*, $i = 1,\ldots,n$. For example, in order to appreciate this degree, it is necessary to arrange the all input variables in decreasing importance so as to satisfy the rule:

$$\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n > 0 \quad \text{and} \quad \sum_{i=1}^{n} \lambda_i = 1. \tag{1}$$

In this study, it is accepted that the all input variables are equal importance, then

$$\lambda_i = \frac{1}{n}, \qquad i = 1,\ldots,n. \tag{2}$$

Here, each input variable Q_i, $i = 1,\ldots,51$ (here, $n = 51$) has a corresponding membership function μ_{ij}^{Q}, $j = 1,\ldots,5$ to the five fuzzy subsets. The membership functions μ_{ij}^{Q} are defined with the following formulae:

$$\mu_{i1}^{Q} = \begin{cases} 1, & 0 \leq Q_i < 0.25 \\ \dfrac{0.75 - Q_i}{0.75 - 0.25}, & 0.25 \leq Q_i < 0.75 \\ 0, & 0.75 \leq Q_i \leq 4 \end{cases}$$

$$\mu_{i2}^{Q}=\begin{cases}0, & 0\le Q_i<0.25\\ \dfrac{Q_i-0.25}{0.75-0.25}, & 0.25\le Q_i<0.75\\ 1, & 0.75\le Q_i<1.25\\ \dfrac{1.75\text{-}Q_i}{1.75-1.25}, & 1.25\le Q_i<1.75\\ 0, & 1.75\le Q_i\le 4\end{cases}$$

$$\mu_{i3}^{Q}=\begin{cases}0, & 0\le Q_i<1.25\\ \dfrac{Q_i-1.25}{1.75-1.25}, & 1.25\le Q_i<1.75\\ 1, & 1.75\le Q_i<2.25\\ \dfrac{2.75\text{-}Q_i}{2.75-2.25}, & 2.25\le Q_i<2.75\\ 0, & 2.75\le Q_i\le 4\end{cases}$$

(3)

$$\mu_{i4}^{Q}=\begin{cases}0, & 0\le Q_i<2.25\\ \dfrac{Q_i-2.25}{2.75-2.25}, & 2.25\le Q_i<2.75\\ 1, & 2.75\le Q_i<3.25\\ \dfrac{3.75\text{-}Q_i}{3.75-3.25}, & 3.25\le Q_i<3.75\\ 0, & 3.75\le Q_i\le 4\end{cases}$$

$$\mu_{i5}^{Q}=\begin{cases}0, & 0\le Q_i<3.25\\ \dfrac{Q_i-3.25}{3.75-3.25}, & 3.25\le Q_i<3.75\\ 1, & 3.75\le Q_i\le 4\end{cases}$$

The membership function "*Question answer level*" for each input variable Q_i, $i=1,\ldots,51$, is calculated.

The results are presented in tables for each of the input variable Q_i, $i=1,\ldots,51$ as shown in Table I.

TABLE I: MEMBERSHIP FUNCTIONS OF INPUT VARIABLE Q_i

Question Q_i	**Weight coefficient** λ_i^Q	**Membership functions** μ_{ij}^Q **of** Q_i				
		VS	***S***	***M***	***B***	***VB***
Q_1	λ_1^Q	μ_{11}^Q	μ_{12}^Q	μ_{13}^Q	μ_{14}^Q	μ_{15}^Q
…						
Q_i	λ_i^Q	μ_{i1}^Q	μ_{i2}^Q	μ_{i3}^Q	μ_{i4}^Q	μ_{i5}^Q
…						
Q_{51}	λ_{51}^Q	$\mu_{51,1}^Q$	$\mu_{51,2}^Q$	$\mu_{51,3}^Q$	$\mu_{51,4}^Q$	$\mu_{51,5}^Q$

The value r_k of the each intermediate variable R_k $k=1,.,3$ (R : "*Risk assessment*", "*Risk management planning*", "*Implementing risk prevention and preparedness measures*"), as output variable in regard to all the defined questions Q_i, $i=1,\ldots,51$ are calculated as follows:

$$r_k=\sum_{j=1}^{5}\alpha_j^R\sum_{i=1}^{51}\lambda_i^Q\mu_{ij}^Q ,$$

or (4)

$$r_k=\sum_{j=1}^{5}\alpha_j^R v_j^Q , \quad \text{where } v_j^Q=\sum_{i=1}^{51}\lambda_i^Q\mu_{ij}^Q$$

A node point vector $\alpha^R=\left(\alpha_1^R,\alpha_2^R,\alpha_3^R,\alpha_4^R,\alpha_5^R\right)$ is introduced. In this investigation the node point vector has following elements $\alpha^R=(1,3,5,7,9)$.

The classification of the current value r_k of the each intermediate variable R_k , $k=1,.,3$ as output variable are carried out using the constructed criterions to split the set R into fuzzy subsets given in Table II.

Thereby, an effective and useful linguistic classification of the each intermediate variable R_k , $k=1,.,3$ ("*Risk assessment*", "*Risk management planning*", "*Implementing risk prevention and preparedness measures*"), as output variable in regard to all the defined questions ($n=51$) is completed.

Further the intermediate variables R_k , $k=1,.,3$ ("*Risk assessment*", "*Risk management planning*", "*Implementing risk prevention and preparedness measures*") are considered as input variables of the fuzzy logic subsystem on the second level. For this reason, each input variable R_k , $k=1,.,3$ has a corresponding membership function μ_{kj}^R , $j=1,\ldots,5$ to the five fuzzy subsets. The membership functions μ_{kj}^R are defined with the following formulae:

The membership functions μ_{kj}^R are defined with the following formulae:

$$\mu_{k1}^{R}=\begin{cases}1, & 0\le R_k<1.5\\ 2.5\text{-}R_k, & 1.5\le R_k<2.5\\ 0, & 2.5\le R_k\le 10\end{cases}$$

$$\mu_{k2}^{R}=\begin{cases}0, & 0\le R_k<1.5\\ R_i-1.5, & 1.5\le R_k<2.5\\ 1, & 2.5\le R_k<3.5\\ 4.5\text{-}R_i, & 3.5\le R_k<4.5\\ 0, & 4.5\le R_k\le 10\end{cases}$$

(5)

$$\mu_{k3}^{R}=\begin{cases}0, & 0\le R_k<3.5\\ R_k-3.5, & 3.5\le R_k<4.5\\ 1, & 4.5\le R_k<5.5\\ 6.5\text{-}R_k, & 5.5\le R_k<6.5\\ 0, & 6.5\le R_k\le 10\end{cases}$$

$$\mu_{k4}^{R}=\begin{cases}0, & 0\le R_k<5.5\\ R_k-5.5, & 5.5\le R_k<6.5\\ 1, & 6.5\le R_k<7.5\\ 8.5\text{-}R_k, & 7.5\le R_k<8.5\\ 0, & 8.5\le R_k\le 10\end{cases}$$

$$\mu_{kj}^{R} = \begin{cases} 0, & 0 \le R_k < 7.5 \\ R_k - 7.5, & 7.5 \le R_k < 8.5 \\ 1, & 8.5 \le R_k \le 10 \end{cases}$$

The membership function "*Intermediate variable level*" for each input variable $R_k, k = 1,..3$ is calculated. The results are presented in tables for each of the input variable $R_k, k = 1,..3$ as shown in Table III.

The value a of the "*Assessment of risk management capability", A* as system output variable in regard to all the defined questions Q_i , $i = 1,\ldots,51$ and in particular to the three intermediate variable are calculated as follows

$$a = \sum_{j=1}^{5} \alpha_j \sum_{k=1}^{3} \lambda_k \mu_{kj} ,$$

or (6)

$$a = \sum_{j=1}^{5} \alpha_j \nu_j , \quad \text{where } \nu_j = \sum_{k=1}^{3} \lambda_k \mu_{kj}$$

A node point vector $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5)$ is introduced. In this investigation the node point vector has following elements $\alpha = (10,30,50,70,90)$.

TABLE II: LEVEL CLASSIFICATION OF THE INTERMEDIATE VARIABLE AS OUTPUT VARIABLE

Value interval of intermediate variable, r	Level classification of intermediate variable as output variable, R_i	Membership function of the intermediate variable as output variable, μ_j^R
$0 \le r \le 1.5$	R_1	1
$1.5 < r < 2.5$	R_1	$\mu_1^R = 2.5 - r$
	R_2	$1 - \mu_1^R = \mu_2^R$
$2.5 \le r \le 3.5$	R_2	1
$3.5 < r < 4.5$	R_2	$\mu_2^R = 4.5 - r$
	R_3	$1 - \mu_2^R = \mu_3^R$
$4.5 \le r \le 5.5$	R_3	1
$5.5 < r < 6.5$	R_3	$\mu_3^R = 6.5 - r$
	R_4	$1 - \mu_3^R = \mu_4^R$
$6.5 \le r \le 7.5$	R_4	1
$7.5 < r < 8.5$	R_4	$\mu_4^R = 8.5 - r$
	R_5	$1 - \mu_4^R = \mu_5^R$
$8.5 \le r \le 10$	R_5	1

The classification of the current value a of the "*Assessment of risk management capability",* as output variable are carried out using the constructed criterions to split the set A into fuzzy subsets given in Table IV.

Thereby, an effective and useful linguistic classification of the "*Assessment of risk management capability",* as output variable in regard to all the defined questions ($n = 51$) and to the three intermediate variable is completed.

TABLE III: MEMBERSHIP FUNCTIONS OF INTERMEDIATE VARIABLE AS INPUT VARIABLE R_k

Question R_k	**Weight coefficient** λ_k^R	**Membership functions** μ_{ij}^Q **of** Q_i				
		VS	***S***	***M***	***B***	***VB***
R_1	λ_1^R	μ_{11}^R	μ_{12}^R	μ_{13}^R	μ_{14}^R	μ_{15}^R
R_2	λ_2^R	μ_{21}^R	μ_{22}^R	μ_{23}^R	μ_{24}^R	μ_{25}^R
R_3	λ_3^R	μ_{31}^R	μ_{32}^R	μ_{33}^R	μ_{34}^R	μ_{35}^R

TABLE IV: LEVEL CLASSIFICATION OF THE INTERMEDIATE VARIABLE AS OUTPUT VARIABLE

Value interval of intermediate variable, r	Level classification of system output variable, A	Membership function of the system output variable, μ_j
$0 \le a \le 15$	A_1	1
$15 < a < 25$	A_1	$\mu_1 = 25 - r$
	A_2	$1 - \mu_1 = \mu_2$
$25 \le a \le 35$	A_2	1
$35 < a < 45$	A_2	$\mu_2 = 45 - r$
	A_3	$1 - \mu_2 = \mu_3$
$45 \le a \le 55$	A_3	1
$55 < a < 65$	A_3	$\mu_3 = 65 - r$
	A_4	$1 - \mu_3 = \mu_4$
$65 \le a \le 75$	A_4	1
$75 < a < 85$	A_4	$\mu_4 = 85 - r$
	A_5	$1 - \mu_4 = \mu_5$
$85 \le a \le 100$	A_5	1

IV. CONCLUSIONS

The fuzzy logic method for assessment of risk management capability is proposed. The fuzzy logic method is developed as a two level hierarchical system with several inputs and one output. The obtained results can support the assessment of risk management capability on Member State, either at national or the appropriate sub-national level.

The proposed method for the assessment of risk management capability is envisaged to be implemented as a part of the information system for integrated risk management of natural disasters. This system can be successfully used in e-government.

APPENDIX

Questions	Levels				
Risk Assessment					
Question 1: Does the risk assessment fit within an overall framework?	n/a	(1)	(2)	(3)	(4)
Question 2: Are clearly defined responsibilities and roles/functions assigned to the relevant entities participating in the risk assessment?	n/a	(1)	(2)	(3)	(4)

Question 3: Are the responsibilities to assess specific risks relevant for the risk assessment allocated to the most relevant entities?	n/a	(1)	(2)	(3)	(4)
Question 4: Has the cross-sectorial dimension of risks been integrated in the risk assessments carried out at Member State and/or sub-national level?	n/a	(1)	(2)	(3)	(4)
Question 5: Is the distribution of responsibilities for the assessment of the risks regularly reviewed?	n/a	(1)	(2)	(3)	(4)
Question 6: Are the experts responsible for the risk assessment(s) adequately informed, trained and experienced in the assessment of risks?	n/a	(1)	(2)	(3)	(4)
Question 7: Are relevant stakeholders involved in the risk assessment process?	n/a	(1)	(2)	(3)	(4)
Question 8: Is the necessary administrative capacity available at national and/or appropriate sub-national level to communicate the results of risk assessments to the public?	n/a	(1)	(2)	(3)	(4)
Question 9 Is the necessary administrative capacity available at national and/or appropriate sub-national level to communicate internally the results of risk assessments, including scenarios, lessons learnt?	n/a	(1)	(2)	(3)	(4)
Question 10: Are the results of risk assessments integrated in a risk communication strategy?	n/a	(1)	(2)	(3)	(4)
Question 11: Has the national or sub-national entity developed a methodology for risk assessment? Is this methodology laid down or published and what are the key elements of this methodology?	n/a	(1)	(2)	(3)	(4)
Question 12: Has the cross-border dimension of risks been integrated in the risk assessments carried out at Member State and/or sub-national level?	n/a	(1)	(2)	(3)	(4)
Question 13: Are infrastructure included in the assessment of risks carried out at Member State and/or sub-national level?	n/a	(1)	(2)	(3)	(4)
Question 14: Are IT/ICT infrastructure (or other relevant infrastructure) available to carry out risk assessments at national and/or appropriate sub-national level?	n/a	(1)	(2)	(3)	(4)
Question 15: Is appropriate information and data (including historical data) available to carry out risk assessments at national and/or appropriate sub-national level?	n/a	(1)	(2)	(3)	(4)
Question 16: Do you have the financial capacity to carry out and update your work on risk assessments?	n/a	(1)	(2)	(3)	(4)
Risk Management Planning					
Question 17: Are clearly defined responsibilities and roles/functions assigned to the entities participating in the planning of risk prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 18: Are the responsibilities to deal with specific risks ensured and regularly assessed?	n/a	(1)	(2)	(3)	(4)
Question 19: Are sufficient experts available to carry out the planning of prevention and preparedness measures based on the identified risks in the risk assessment?	n/a	(1)	(2)	(3)	(4)
Question 20: Is there effective training available for the experts at different levels responsible for the planning of prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 21: Are the experts involved in the planning of prevention and preparedness measures informed about the overall policy objectives / priorities related to disaster risk management?	n/a	(1)	(2)	(3)	(4)
Question 22: Is there a process in place to ensure that the knowledge of experts tasked with the planning of prevention and preparedness measures is preserved and further developed?	n/a	(1)	(2)	(3)	(4)
Question 23: Do the different responsible national or sub-national entities have methodologies developed for risk management planning? What are the key elements of these methodologies?	n/a	(1)	(2)	(3)	(4)
Question 24: Do methodologies for risk management planning include the identification of infrastructure relevant for the mitigation of identified risks?	n/a	(1)	(2)	(3)	(4)
Question 25: Are the relevant public and private stakeholders informed and involved in the planning process?	n/a	(1)	(2)	(3)	(4)
Question 26: Are any of the risks identified in the risk assessments shared with public or private companies, and if so, how is it ensured that the planning of prevention and preparedness measures by these companies is done to sufficient quality?	n/a	(1)	(2)	(3)	(4)
Question 27: Are the national or sub-national entities involved in cross-border planning of prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 28: Are relevant stakeholders, including citizens, informed about the key elements of risk management planning?	n/a	(1)	(2)	(3)	(4)
Question 29: Are equipment and tools needed to support and/or carry out the planning of prevention and preparedness measures available?	n/a	(1)	(2)	(3)	(4)
Question 30: As part of the planning process, are financing needs for the implementation of prevention and preparedness measures estimated and possible sources of financing identified?	n/a	(1)	(2)	(3)	(4)
Question 31: As part of the planning process, are future investment plans and the possible role of private sector financing considered?	n/a	(1)	(2)	(3)	(4)
Question 32: As part of the planning process, are procedures or plans identified or established ahead to ensure financing is in place for the prevention and preparedness measures needed to mitigate the identified risks?	n/a	(1)	(2)	(3)	(4)
Implementation of prevention and preparedness measures					
Question 33: Is the implementation of prevention and preparedness measures linked to the risk management planning? Is it part of a strategy or policy and was a methodology defined?	n/a	(1)	(2)	(3)	(4)
Question 34: Are methods for damage reporting developed and are the costs of damages estimated, documented and stored?	n/a	(1)	(2)	(3)	(4)
Question 35: Are clearly defined responsibilities and roles/functions assigned to the entities participating in the implementation of risk prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 36: Is the distribution of responsibilities of experts involved in the implementation of prevention and preparedness measures up to date and are sufficient resources available to implement prevention and preparedness measures based on the planning process?	n/a	(1)	(2)	(3)	(4)
Question 37: Are the experts responsible for the implementation of prevention and preparedness measures adequately trained, experienced and informed?	n/a	(1)	(2)	(3)	(4)
Question 38: Are the relevant stakeholders informed and involved in the implementation of prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 39: Is the national or sub-national entity involved in the implementation of cross-border measures for prevention and preparedness?	n/a	(1)	(2)	(3)	(4)

Question 40: Is the implementation of prevention and preparedness measures by these public or private stakeholders done in sufficient quality to achieve the expected risk mitigation results?	n/a	(1)	(2)	(3)	(4)
Question 41: Does the implementation of prevention and preparedness measures include for example the development of procedures for early warning, activation, dispatching, deactivation or monitoring?	n/a	(1)	(2)	(3)	(4)
Question 42: Is the necessary information available and regularly exchanged inside the national or sub-national entity?	n/a	(1)	(2)	(3)	(4)
Question 43: Are communication strategies in place, including the use of various media tools (including social media) to effectively share information with citizens to increase awareness and to build trust and confidence?	n/a	(1)	(2)	(3)	(4)
Question 44: Is the condition of the infrastructure relevant for the implementation of prevention and preparedness measures analysed?	n/a	(1)	(2)	(3)	(4)
Question 45: Does the implementation of prevention and preparedness measures include the identification of possible equipment needs based on an existing inventory of available equipment needed to carry out the planned prevention and preparedness measures?	n/a	(1)	(2)	(3)	(4)
Question 46: Are supply chain risks identified during the implementation of prevention and preparedness measures and were measures taken to reduce the risk of supply shortages?	n/a	(1)	(2)	(3)	(4)
Question 47: Do the experts tasked with the implementation of prevention and preparedness measures have the necessary technical expertise to ensure the adequate implementation of the measures and is ensured that this knowledge is preserved and further developed?	n/a	(1)	(2)	(3)	(4)
Question 48: Do the experts tasked with the implementation of prevention and preparedness measures have the knowledge to apply procurement and logistics procedures to carry out these tasks and have the experts adequately trained to apply these procedures?	n/a	(1)	(2)	(3)	(4)
Question 49: Do the experts tasked with the implementation of prevention and preparedness measures have the knowledge to do life cycle and surge capacity planning and are these methodologies applied to review the functioning of equipment and systems and to be able to increase capacity in the case of an emergency?	n/a	(1)	(2)	(3)	(4)
Question 50: When carrying out prevention and preparedness measures needed to mitigate the identified risks, are a budget, a legal base and procedures identified or established to plan ahead for flexible resource allocation?	n/a	(1)	(2)	(3)	(4)
Question 51: Does the implementation of prevention and preparedness measures include the preparation of agreements with stakeholders that regulate the sharing of costs	n/a	(1)	(2)	(3)	(4)

ACKNOWLEDGMENT

The authors express their gratitude to the Bulgarian National Science Fund for the financial support under the Grant № DFNI-I02/ 15 from 2014, titled "Information System for Integrated Risk Assessment from Natural Disasters".

REFERENCES

[1] *United Nation`s Global Assessment Report on Disaster Risk Reduction*, 2015.
[2] *Press release*, 04 June 2015-UNISDR 2015/23.
[3] D. Velev and P. Zlateva, "An innovative approach for designing an emergency risk management system for natural disasters," *International Journal of Innovation, Management and Technology*, vol. 2, no. 5, pp. 407-413, 2011.
[4] P. Zlateva, Y. Hirokawa, and D. Velev, "An integrated approach for risk assessment of natural disasters using cloud computing," *International Journal of Trade, Economics and Finance*, vol. 4, no. 3, pp. 134-138, 2013.
[5] P. Zlateva and D. Velev, "Complex risk analysis of natural hazards through fuzzy logic", *Journal of Advanced Management Science*, vol. 1, no. 4, pp. 395-400, 2013.
[6] P. Zlateva, L. Pashova, K. Stoyanov, and D. Velev, "Social risk assessment from natural hazards using fuzzy logic," *Int. Journal of Social Science and Humanity*, vol. 1, no. 3, pp. 193-198, 2011.
[7] Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism, OJL (347), December 20, 2013.
[8] Commission staff working paper "Risk assessment and mapping guidelines for disaster management," SEC (2010) 1626 final of 21.12.2010.
[9] ISO/IEC 31010:2009, *Risk management - Risk Assessment Techniques*
[10] UNISDR: *UN International Strategy for Disaster Reduction Sec*. (January 15, 2009). [Online]. Available: http://www.unisdr.org/eng/library/.
[11] *Flood Risk Management Plans under the Floods*, Directive 2007/60/EC, 2007.
[12] Good practices in disaster prevention. Publications and Reports in *The European Climate Adaptation Platform* (Climate-ADAPT) (2013). [Online]. Available: http://climate-adapt.eea.europa.eu/viewaceitem?aceitem_id=7215
[13] Prevention, Glossary, in *The European Climate Adaptation Platform* (Climate-ADAPT) (2013). [Online]. Available: http://climate-adapt.eea.europa.eu/
[14] Draft of the Guidelines for the *Risk Management Capability Assessment*, European Commission, 2014.

Plamena Zlateva is currently an associate professor at the Institute of System Engineering and Robotics at the Bulgarian Academy of Sciences, Sofia, Bulgaria. She hods the M.Sc. degrees in applied mathematics from the Sofia Technical University and in economics from the Sofia University St. Kl. Ohridski, and the Ph.D. degree in manufacturing automation from the Institute of Conrol and System Research - BAS. Her main areas of academic and research interest are control theory, mathematical modeling and risk management.

Dimiter Velev is a professor in the Department of Information Technologies and Communications at the University of National and World Economy, Sofia, Bulgaria. He holds the M.Sc. degree in electroengineering from the Sofia Technical University, Bulgaria and the Ph.D. degree in engineering sciences from the Institute of Modeling Problems in power engineering at the National Academy of Sciences of Ukraine, Kiev, Ukraine. His main areas of academic and research interest are internet-based business systems modeling and development, service oriented architectures, online social networks, cloud computing, web applications development and programming.

Lyubomira Raeva is a desk officer in International Cooperation, NATO, EU and Humanitarian Operations Department of the DG Fire Safety and Civil Protection, Ministry of Interior, Bulgaria.