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6th INTERNATIONAL SYMPOSIUM ON NATURAL RESOURCES MANAGEMENT

Urednici/Editors
Dragan Mihajlović
Bojan Đorđević

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6. MEĐUNARODNI SIMPOZIJUM O UPRAVLJANJU PRIRODNIM RESURSIMA JE FINANSIJSKI PODRŽAN OD MINISTARSTVA PROSVETE, NAUKE I TEHNOLOŠKOG RAZVOJA REPUBLIKE SRBIJE

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NATURAL RESOURCES CATASTROFIC RISK ASSESSMENT MODELING

MODELIRANJE PROCENE RIZIKA OD KATASTROFA PRIRODNIH RESURSA

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ABSTRACT

Catastrophic risk represents the individual risk which endangers a relatively large number of people, property, environment and natural resources. In this context, special attention is on the catastrophic risk identification, their analysis, assessments and management. Therefore, it is necessary to seek for adequate models for managing these risks; including the funding plans and arrangements in function to eliminate the harmful consequences of their realization as well as preventive and reduction measures for minimize their adverse effects. In this paper we focused on manage catastrophic risks prior to preventive measures and insurance.

KEY WORDS

catastrophic risks, risk modeling, insurance

APSTRAKT

Rizik od katastrofa predstavlja pojedinačni rizik koji ugrožava relativno veliki broj ljudi, imovinu, životnu sredinu i prirodne resurse. U ovom kontekstu, posebna pažnja se posvećuje prepoznavanju rizika od katastrofa, njihovoj analizi, proceni i upravljanju. Samim tim, neophodno je tragati za odgovarajućim modelima upravljanja ovim rizicima; uključujući finansiranje planova i aranžmana u funkciji otklanjanja štetnih posledica tokom njihove realizacije kao i preventivne i reduktivne mere za minimiziranje njihovih štetnih uticaja. U ovom radu se radije fokusiramo na upravljanje rizicima od katastrofa nego na preventivne mere i osiguranje.

KLJUČNE REČI

Rizici od katastrofa, modeliranje rizika, osiguranje

1. INTRODUCTION

Natural disasters, especially those associated with climate change (and there are more than 90% of such disasters in the last two decades), represent a constant threat to sustainable development. They have an adverse effect on every aspect of development. Unfortunately, their distributions tend to be fat-tailed, implying on extreme outliers if catastrophes occur. These two factors imply that the occurrence and consequences of catastrophes will be difficult to predict. Natural disasters and sustainable development are closely interlinked. Development is never neutral in relation to catastrophes: it creates, enhances or reduces the risk of their occurrence. Natural hazards, by themselves, do not cause disasters. They arise as result of exposure, vulnerability and poor preparedness for dealing with hazardous events. Inadequate models of development promote the emergence of natural disasters, which, on their side, appear as an obstacle to sustainable development.

In May 2014, Serbia and the region suffered catastrophic flood damages. Material damages in Serbia were estimated at about 4.5% of the country's GDP or 1.5 billion euros. The paid insurance indemnity, on the other hand, amounted to only 38.3 million euros and/or 0.1% of Serbia's GDP (Janković and Tešić, 2015). Among other, damage caused industrial and mining production, which led to release of hazardous substances and waste into the environment, which led to polluted by surface, groundwater and soil, as well as to secondary impact on ecosystems and wildlife world. Damage caused homes and buildings has created over 500,000 tons of waste. (Vidojević, Dimić and Baćanović, 2015)

Public and private sector have important roles in catastrophe risk management. Efficient financing of catastrophe risks can be achieved through public-private partnerships between private insurer, reinsurers and government. In this paper we focused on manage catastrophic risks prior to their realization through preventive measures and insurance. Catastrophic risks insurance is the national interest. Preserving the material interests of the entire national economy and society imposes the need for active participation of the state in the field of encouraging insurance of catastrophic risks. It is necessary to enforce a properly quantification of catastrophic risks and set appropriate models. In this paper we introduce four models for quantifying catastrophic risks.

2. CATASTROPHIC RISKS

The European Commission has classified catastrophic risks into two main groups. The first group comprises natural disasters risks, which have been further classified into subgroups based on the highest frequency with which they occur in the territory of the EU (floods, bad weather conditions, pandemic / epidemic, forest fires and earthquakes). The second group consists of risks caused by human carelessness or negligence, or by intention, resulting in failures and mishaps happening in the vicinity of industrial systems and settlements. They are also called technological risks.

Nat Cat Risks	Technological Risks
Floods	Industrial accidents
Severe weather	Nuclear/radiological accidents
Pandemics/epidemics	Transport accidents
Livestock epidemics	Cyber attacks
Wild/Forest fires	Terrorist attacks
Earthquakes	Loss of critical infrastructure
Landslides	Public disorder
Droughts	Marine/coastal pollution
Space weather	Water/food contamination
Volcanic eruptions	CBRN attacks
Harmful organisms	Refugees/unmanaged migration
Tsunamis	Environmental pollution

2.1. Natural Catastrophic risks

The term natural disaster refers to an event caused by the action of natural forces. Such an event generally results in a large number of individual losses and includes a large number of insurance policies. The extent of the damage, as a result of a disaster, depends not only on the strength of natural forces action, but also on other factors such as building constructions, design or the efficiency of disaster control in this region, the result of which could be financial, environmental and human losses. Natural disasters are divided into the following categories: floods, storms, earthquakes, droughts/forest fires/heat waves, cold waves/frost, hail, tsunami and others.

The number of floods and serious rainfall in Europe has increased in recent years. Among the disasters associated with climate, flooding has far the largest share, accounting for 43%. Current EU projections indicate that the risk arising from storms in Europe would also increase as a result of climate changes. So far, there have been no systematic risk assessments of drought at the European level.

Natural disasters often act as a trigger for technological risks and damages. The damage done to chemical plants or oil and gas pipelines, inter alia, causes the release of hazardous substances. These events are called Natech accident. Currently, there is little knowledge about the dynamics of Natech accidents and the situation is aggravated due to the expected increase of the Natech risk, due to the development of society, climate changes etc.

2.2. Technological risks

Industrial accidents - significant quantities of hazardous materials are processed or stored in industrial facilities which constitute the main source of risks of industrial damage to human population as well as environment. Substances can be considered hazardous if they pose a risk to human health (such as acute toxic substances), if they involve physical hazards (e.g. explosive, highly flammable substances) or the hazard to environment. Frequent incidents with hazardous substances in chemical plants, petrochemical and oil refinery; indicate the need for better and more efficient control. Prevention should aim not only to prevent major catastrophes from happening, as it was the case with the fire in a warehouse at the Buncefield Oil (UK, 2005) or ammonium nitrate explosion in Toulouse (France, 2001), but also to prevent those minor ones threatening the security of the community, workplaces safety and a clean and healthy environment.

After the accident at the Fukushima reactor (Japan) in 2011, it was agreed that all nuclear power plants in the EU had to be reviewed by independent bodies and undergo a comprehensive and transparent risk and safety assessment, or 'stress tests'. Stress tests (2011-12) were done for the effects of earthquakes and floods as well. Currently in the EU there are 131 (in Europe 185) nuclear reactors.

Insurance companies in western countries struggle to cancel the impact of power plants that increase the risk of natural disasters. Swedish state power company, Vattenfall, and the Swedish private insurance company, Skandia, are jointly investing almost 264 million US dollars to build four wind farms in Sweden with a total output of 141 MW.

2.3. Macro Catastrophic Risks

There are many other extreme events, in addition to natural disasters that constitute a risk of the loss at a global level. These catastrophic risks are yet to be studied in greater detail as science has made not sufficient progress in their examination. In recent years, however, there have been a series of events that were very destructive on a global level, caused by the volcanic ash cloud, epidemics, social unrest, cyber-attacks, as well as a wide range of other geopolitical, technological, financial, and other events that have influenced the environment and economy. Like with any new type of event, the society does not respond promptly enough in identifying hazards and, consequently, determining new security measures.

3. CATASTROPHIC RISKS MANAGEMENT

A proactive approach to managing catastrophe risks at national level is indispensable. According to the guidelines of the World Bank (Cummins and Mahul, 2009), such approach should be based on:

- *risk assessment,* as the key pillar of the catastrophe risk management process. The size of catastrophe risk is conditioned by the frequency and intensity of hazards, but also by tangible and intangible resources that are exposed to the risk, as well as their sensitivity. Catastrophe risk assessment is based on empirical data and sophisticated probabilistic models enabling simulation of the impact of extreme events;
- *building institutional capacities,* in terms of knowledge, skills and capacity of relevant institutions, including the government, but also provincial and local government authorities and the local community to adequately respond to emerging situations;

- *investing in preventive and repressive measures,* that contribute to reduction of catastrophe risk consequences;
- *strengthening preparedness for emergency situations,* i.e. enhancing the ability of people to respond to the disaster, through the emergency communications systems, public awareness, appropriate technical capacities, etc.;
- *financing catastrophe risks* in such a manner that needs for rehabilitation of damages are fully satisfied without endangering the long-term development objectives of the country.

Invest in protection

Decision-makers are reluctant to protect themselves against low-probability, high-consequence events (Kunreuther and Heal, 2012). In function to review how protective decisions should ideally be made we can set following assumptions:

1. All decision-makers follow the economic rationality of utility maximization.
2. Decision-maker is considering investment that has potential payoffs for the next T years.
3. Annual probability p of a catastrophic loss in any given year t.
4. B_a is an annual benefit of investing in a measure that reduces the consequences of the disaster should such an event occur.
5. r is the annual discount rate

Then, the decision to protect against this event could be made by observing whether the upfront cost C of the investment is less than the discounted stream of expected benefits (*pB*); that is, if

$$C < \sum_{t=1}^{T} (pB_a)\mathrm{r}^t \,. \qquad (1)$$

Formula (1) indicates that all future benefits are discounted exponentially and that individuals can estimate future probabilities of a disaster. And further, individuals can estimate the costs and benefits of the risk reduction measure.

In practice, decision-makers are likely to utilize simplified choice rules, focus on constraints as well as short-run benefits and costs rather than discounting the future exponentially and may not consider probabilities in their decision on whether or not to invest in the risk-reduction measure (Kahneman and Tversky, 2000).

The simplest explanation as to why decision-makers may fail to invest in protection is affordability. If the decision-maker has limited capital on hand, there may be little point in undertaking a benefit-cost analysis of whether to incur the upfront cost of investing in protection.

Insurance premium

In most European countries, insurance against natural disasters risk is sold on a voluntary basis alongside with a basic insurance or as optional. In Romania, flood and earthquake insurance is mandatory, while in the Netherlands it is not possible to be insured against floods and earthquakes, so in the case of these risks the government takes responsibility for the claims compensation for the damages on ex post basis. For countries with high exposure to these risks, such as Belgium, France and Estonia, there are insurance packages covering Nat Cat risks. Limits and insured participation in damage also vary from country to country. These are mostly fixed amounts or a certain percentage of the insured sum. The insurance premium is very heterogeneous and may be based on a risk basis or flat pricing.

The role of government

The role of the state is also variable, depending of each country's individual policy. In some countries, the state is included in the ex-ante planning, while in others it only provides the financial means for ex-post compensation. Special funds that cover a certain part of the damage are very common. However, in the last few years, there have been some evident changes in this area, and the government is acquiring a greater role as far as Nat Cat risk is concerned.

Generally speaking, the intervention in terms of Nat Cat risks has three main forms (Kerkez and Pavlović, 2015):

- Prevention - reduction of likelihood and impact of Nat Cat.
- Insurance - regulation of private companies providing Nat Cat insurance, with clear terms and conditions of this insurance, etc.
- The role of Government - support for the casualties, the restoration of public services, the creation of special funds, soft loans for the vulnerable and so on.

4. CATASTROPHE RISK MODELING

Selection of appropriate methods, techniques and models for risk assessment in relation to the specific features and characteristics of the considered system and available information and resources, is a key parameter of reliability assessment. Risk assessment is primarily aimed at quantifying the amount of total risk, but includes all procedures that enable quantification of elements and sub-elements of the total risk, as well as procedures after a risk assessment, such as testing, implementation and other possible adjustments.

4.1 Scenario method

Routine practice in risk management is to prepare clear scenarios. They are used to develop the "elasticity" of the systems that are being managed. The scenario certainly cannot and will not accurately predict the actual following crises, thus the choice of the scenario represents a kind of exercise in avoiding ad hoc ones. It is commonly stated that the future crisis events are unpredictable, and that the complexity of catastrophic events and disturbances taking place are too coincidental and with so many potential future permutations to be considered. Stress test scenarios are frequently used method to research the risk effects and management. Stress tests can improve the resistance to different types of damaging events. In the selection of scenarios for various individual threats, it is important that they are comparable and standardized on the basis of the same probability of occurrence. Probabilistic catastrophic models and stochastic - mathematical modeling are used for this purpose.

There are four groups of data which must be included in the model:

- Hazard: where, how often and with what intensity adverse events occurred?
- Vulnerability: what is the damage caused by an event?
- Exposure: where are different types of insured objects and what are their values?
- Insurance conditions: what proportion of the damage is insured?

This approach can be applied to all kinds of risks that lead to natural disasters: earthquakes, storms, floods, etc. Some catastrophic risks are not easy to identify and include in traditional insurance products. However, there is a potential for new classes of insurance and a new approach to product design.

We can define function R as:

$$R = \{(S_i, \mathrm{P}_i, X_i), i = 1, 2, ...\}$$

where:

- Si- *i*-th risk scenario, description of loss events that may occur,
- Pi- probability of realization of the *i*-th scenario,
- Xi-consequences in the case of realization of *i*-th scenario.

More clearly, the variable S_i is an answer to the question *„What can go wrong?"* and represent possible scenarios. It is structured, organized and complete set of possible risk scenarios.

The variable P_i is an answer to the question *„What is the probability of that to happen?"* and represent the probability of each scenario S_i.

The variable X_i is an answer to the question *„What are the consequences if that happens?"* and describe the final state in the case of the realization of the *i*-th scenario (Kaplan and Garrick 1981). The uncertainty must be quantified as part of the quantifying risks process.

During the forming of probability distribution curves, in the process of quantifying risks, there is a parametric uncertainty. Using the available evidence and basic mathematical principles of logical reasoning a probability distribution curve can be defined. In this sample we used Bayes theorem. According to the Bayes theorem changes in the probability $P(H)$ can be determined for a given hypothesis H if there is new evidence A.

$$P(H|A) = P(H)P(A|H)/P(A) \tag{2}$$

Equation (2) is the Bayes formula and it tells us that the probability of the hypothesis H changes when we come to new evidence A.

4.2 Non-cooperative games model and optimality principle

Game theory the study of mathematical models of conflict and cooperation between intelligent rational agents. The main goal is finding the optimal set of rules (in a form of strategies) for each player. Every subject in a conflict situation has a set of possible choices in some interaction, or conflict situation that is modeled. Strategy is one of the given possible actions of a player. Non-cooperative game theory is concerned with the analysis of strategic choices. The paradigm of non-cooperative game theory is that the details of the ordering and timing of players' choices are crucial to determining the outcome of a game. Non-cooperative game theory models the situations in which the optimal solution for every player is conditional on other players' actions.

In some cases, normal form game is not good enough to efficiently model economic interaction. Extensive form games are often used to model dynamic interaction between players. In an extensive game, a strategy is a complete plan of choices, one for each decision point of the player. The elements of an extensive game are (Fudenberg and Tirole, 1995):

(1) The set of players.
(2) The order of moves, i.e. who moves when?
(3) What the players' choices are when they move?
(4) The players' payoff as a function of the moves that were made.
(5) What each player knows when he makes his choices?
(6) The probability distribution over any exogenous events.

Extension form game is defined as a system:

$$G = \left\langle I, T, A, \{X_i\}_{i\in I}, \{H_i\}_{i\in I}, \{N_i\}_{i\in I} \right\rangle.$$

Two stage governing system model of agents' interaction is a normal form game

$$G = \left\langle I_0, \{I_i\}, \mathrm{X}_0, \{X_i\}, \mathrm{H}_0, \{H_i\}, \mathrm{i} = 1,2,\ldots,\mathrm{n} \right\rangle. \tag{3}$$

In a game defined by (3) Nash equilibrium exists if following conditions are satisfied:

1. $x_{0i}^*(x_i) \in \mathrm{X}_i(x_i)$ is the solution of parametric LP problem for all

$i = 1,2,...,n, \quad \max\limits_{x_{0i}\in \mathrm{X}_i(x_i)} c_{0i} \cdot x_{0i} = c_{0i} \cdot x_{0i}^*(x_i),$

2. $x_0^*(x_1^*,....,x_n^*) \in X_0$ is the solution of the nonlinear programming problem:

$\max H(x, x(\cdot),...,x(\cdot))$

4.3 The extreme value theory

Identifying catastrophic risks is often associated with the extreme value theory. Pareto distribution can be used for modeling the losses that are above a certain threshold. The distribution function is:

$$F(x) = P(X \le x) = 1-(x/x_0)^b, \text{ for } x_0 = \exp(-a/b).$$

Estimate of parameter b is of a great importance, because if $b \le -1$ then the pure premium has infinite values.

There is a mathematical explanation of why it is used Pareto distribution. The distribution of excesses losses given that is defined by

$$P\left(X-u \le y \middle| X>u\right)=\frac{F(\mathrm{y+u})-\mathrm{F(u)}}{1-F(u)},$$

where is $x_0 \le \infty$ the right endpoint of F and $0 \le y < x_0 - u$ showed that if F is in max-domain of attraction of some extremal distribution function, it holds that the Generalized Pareto distribution

$$G_{\xi,\beta}(x)=\begin{cases}1-(1+\xi x/\beta)^{-1/\xi} & \xi \ne 0\\ 1-\exp(-x/\beta) & \xi = 0\end{cases} \tag{4}$$

is the limiting distribution for the excesses over u, as u tends to the right endpoint x_F. For the distribution function (4) holds $\beta > 0$, and $x \ge 0$ when $\xi \ge 0$ and $0 \le x \le -\beta/\xi$ when $\xi < 0$. ξ is a shape parameter and β is a scaling parameter. It simply means that large loss, under some conditions, can be modeled using the generalized Pareto distribution.

4.4 AHP

In this part of paper, the risk assessment of flood risk used Analytical Hierarchy Process (AHP). AHP method (Saaty, 1977, 1980) is often applied in risk assessment based on the expert knowledge of mutual relationship and the importance of certain elements of risk. The main reason for using this method is the nature of the risk, as a multiparameter, complex measure, which is very difficult to accurately analyze and evaluate. The proposed method is applied on hypothetical data in function to illustrate model. The basic idea of the AHP method is to include and apply the knowledge and experts' experience on the problem to be analyzed. AHP is based on a hierarchical breakdown of certain problems to the hierarchy of elements that are structured into levels. AHP method includes identifying goals and criteria to be compared and evaluated. According to this method, the priority of a determined hierarchical structure of the observed problem is to achieve the goal, at the next level criteria which can be further decomposed into sub-criteria or the new hierarchical levels are defined. At each level of the hierarchical structure, pairs of defined elements are mutually compared, using the significance scale, and then the weight of criteria, sub-criteria and alternatives is determined, and finally total values of alternatives are synthesized. The last level are the alternatives representing the final result of the problem analysis, i.e. weight, quantitative value in relation to the objective. The process of applying AHP method comprises the following steps (Vinod Kumar and Ganesh, 1996; Radivojevic and Gajović, 2014):

Step 1. A hierarchical decomposition of the problem, with the aim set at the highest level, the criteria and sub-criteria at lower levels, and the alternatives at the lowest level.

Step 2. Comparison of pairs of elements at each level of the hierarchy in relation to the elements of the higher level, by applying the Saaty scale from 1 to 9. The decision maker determines the value a_{ij}, of the

elements i and j, where $a_{ij}=1/a_{ji}$, $\forall i,j=1,\ldots,n$, $a_{ij}=1$, $\forall\ i=j$.

Step 3. Setting priorities for each element in relation to a higher hierarchy level – w_{ij} is a priority of the alternative i in relation to the criterion j, where $i=1,\ldots,m$, $j=1,\ldots n$, m, is the number of alternatives, n is the number of criteria.

Step 4. Synthesis of all values of priorities so as to obtain the priority of each element in relation to the objective. W_i is the alternative priority i and is determined as:

$$W_i=\sum_{j=1}^{n} c_j\, w_{ij} \tag{5}$$

where c_j is the criteria priority j, and w_{ij} is the alternative priority i in relation to criterion j.

AHP predicts an analysis of the consistency of decision-makers, with a tolerance of up to 10%. Calculated priorities present significance of elements and alternatives, and are eligible only if comparison matrix are consistent or approximately consistent.

AHP method ensures that gradation of significance of defined criteria and synthesis of alternatives (small, medium or high risk) results in relatively crisp, quantitative value of the total risk in system, based on the sublimation of experience and knowledge of experts. The advantage of the model applied in relation to alternative models consists of the possibility to decompose the total risk in a relatively simple manner, which is difficult to achieve by using other models. Description of the mathematical formulation of the AHP is shown in numerous articles published by Saaty (1977, 1980, 1990). The next table consist anthropogenic risk elements of flooding.

Table 1. The influence of anthropogenic risk elements

	Action	Existence	Description	Values	Influence
1	Disturba (DI)	yes	Plenty	2	High
		no	Almost non	1	Medium
2	Inadequate technical works (IW)	yes	Designed for flood intervals less than 1/100 years	2	High
		no	No Designed for flood intervals more than 1/100 years	1	Medium
3	Shaped cross-section at	no	Inappropriate	2	High
	the plain area of the stream (SP)	yes	Well shaped	1	Medium

In the next table are shown natural risk elements of flooding with their influence.

Table 2. The influence of natural risk elements (adapted from Stefanidis and Stathis, 2013)

	Risk elements	Class	Values	Influence
1	Land use (LU)	Cultivated lands, barren land	3	High
		Shrubs, pastures	2	Medium
		Forests	1	Low
2	Erodibility (ER)	Neogene, flysch, alluvial	3	High
		Schists, limestones	2	Medium
		Crystal igneous	1	Low
3	Watersheds slope (WS)	>35 %	3	High
		15–35 %	2	Medium
		<15 %	1	Low
4	Main stream slope (MS)	>7 %	3	High
		3–7 %	2	Medium
		<3 %	1	Low
5	Permeability (PE)	Neogene, crystal igneous, alluvial	3	High
		Schists, flysch	2	Medium
		Limestone	1	Low
6	Watershed shape (WSH)	Roundish	3	High
		Semi-roundish	2	Medium
		Elongated	1	Low
7	Density of hydrographic (ND)	>3 %	3	High
	network (km/km2)	1.5–3 %	2	Medium
		<1.5 %	1	Low

In order to check the discordances between the pairwise comparisons and the reliability of the obtained weights, the consistency ratio (CR) must be computed. For computing the consistency ratio (CR), the following is CR=CI/RI, where consistency index is CI = $(\lambda_{max}-n)/(n-1)$ and λ_{max} represents the sum of the products between the sum of each column of the comparison matrix (n size) and the relative weights.

RI is the random index representing the consistency of a randomly generated pairwise comparison matrix. Taking into account the above mentioned, two flood hazard indexes were defined, one based on natural factors (N) and one based on anthropogenic factors (A). The equation that relates to these indexes had the following form:

$$N, A = \sum_{j=1}^{n} c_j w_j$$

where N, A is the value of flood hazard for each watershed, *w* is the weight of factors *i* and *c* is the sensitivity score of each sub-factor criterion to flooding. Furthermore, the values that were derived from N and A indexes were grouped into four hazard classes according to the probability of flood occurrence.

Table 3. The comparison matrix of risk elements N and comparison matrix of risk elements A

	LU	ER	WS	MS	PE	WO	ND
LU	1	3	3	5	5	5	5
ER	1/3	1	2	4	4	5	5
WS	1/3	1/2	1	2	3	4	4
MS	1/5	1/4	1/2	1	2	2	3
PE	1/5	1/4	1/3	1/2	1	1	2
WO	1/5	1/5	1/4	1/2	1	1	1
ND	1/5	1/5	1/4	1/3	1/2	1	1

	DI	IW	SP
DI	1	2	3
IW	1/2	1	2
SP	1/3	1/2	1

The relative weight of each element can be calculated using the pairwise comparison method and MATLAB or any other specialized software. The derived weights of the elements and the consistency ratio can be seen in Table 4. These comparisons indicated that the consistency ratio in both cases is rather smaller than 10%, so the weights of the risk elements are considered reliable.

Table 4. Relative weights of natural risk elements and anthropogenic risk elements

Elements N	Weight	Elements A	Weight
LU	0,37	DI	0,54
ER	0,23	IW	0,30
WS	0,15	SP	0,16
MS	0,09		
PE	0,06		
WO	0,05		
ND	0,04		
CR	0,03		0,01

5. CONCLUSION

Managing catastrophe risks at national level is indispensable. Managing process including risk assessment, building institutional capacities, investing in preventive and repressive measures, strengthening preparedness for emergency situations and financing catastrophe risks. It is necessary to enforce a properly quantification of catastrophic risks and set appropriate models. Selection of appropriate methods, techniques and models for risk assessment in relation to the specific features and characteristics of the considered system and available information and resources, is a key parameter of reliability assessment. In this paper we described models for quantifying catastrophic risks, and proposed AHP method for flood hazard. The advantage of this model in relation to alternative models is possibility to decompose the total risk in a relatively simple manner.

REFERENCES

Cummins, J.D. and Mahul, O., 2009. Catastrophe Risk Financing in Developing Countries: Principles for Public Intervention. Washington, D.C.: World Bank, p. 19.

Fudenberg, D. and Tirole, J., 1995. *Game theory*. Cambridge: MIT Press.

Janković, D. and Tešić, N., 2015. Major cat losses in past two decades, *Catastrophic risks and Sustainable development*, Part III, Chapter 10, University of Belgrade, Faculty of Economics Publishing Centre, pp. 161-181.

Kahneman, D. and Tversky, A., 2000. *Choices, Values and Frames*. New York: Cambridge University Press.

Kaplan, S. and Garrick J. 1981. On The Quantitative Definition of Risk*, Risk Analysis* Vol. 11, pp. 11-27.

Kerkez M. and Pavlović B., 2015. Power plants insurance against catastrophic risks, in: Marina Evgenevna Baskakova (eds.): *Catastrophic risks and sustainable development*, University of Belgrade, Faculty of Economics, pp. 201-219.

Kunreuther, H. and Heal G., 2012. Managing Catastrophic Risk, To Be Published in Encyclopedia of Energy, Natural Resources and Environmental Economics, Elsevier.

Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures**.** *Journal of Mathematical Psychology, Vol.* 15, No. 3, pp. 234-281.

Saaty, T.L., 1980*. The Analytic Hierarchy Process*. New York: McGraw-Hill.

Saaty, T.L., 1990. How to make decisions: the analytical hierarchy process**.** *European Journal of Operational Research*, Vol. 48, No.1, pp. 9-26.

Stefanidis, S. and Stathis, D., 2013. Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP), *Nat Hazards,* Vol. 68, pp. 569–585.

Vidojević D., Dimić B. and Baćanović N., 2015. *Uticaj katastrofalnih poplava 2014. godine na stanje zemljišta u Republici Srbiji*, Ministarstvo poljoprivrede i zaštite životne sredine, Agencija za zaštitu životne sredine.

Radivojević, G. and Gajović, V., 2014. Supply chain risk modeling by AHP and FAHP methods. *Journal of Risk Research*, Vol. 17, No. 3, pp. 337-352.

Vinod Kumar, N. and Ganesh, L.S., 1996. An empirical analysis of the use of the Analytic Hierarchy Process for estimating membership values in a fuzzy set. *Fuzzy Sets and Systems*, Vol. 82, No. 1, pp. 1-16.