COMPARATIVE METHODS FOR THE EVALUATION OF THE NATURAL RISK FACTORS' IMPORTANCE

Adrian Grozavu[1], Sergiu Pleşcan[2], Ciprian Mărgărint[3]

Keywords: analytic hierarchy process (AHP), factor weights, natural risks assessment.

Abstract. Among the methods for the evaluation of natural and anthropic risks, those of the questionnaire and Analytic Hierarchy Process (AHP) allow evidencing the exposure degree to hazards and also the assessment of factor weights in human communities' degree of vulnerability. In the present study, the two methods have been applied in the analysis of the territory of Lepşa-Greşu Depression, located in Vrancea Mountains from the Eastern Carpathians, potentially threatened by different risk phenomena, such as heavy rains, flash floods, landslides and earthquakes. The application of the questionnaire revealed a weak and diffuse perception on the risk phenomena among the population and also correlations and variations in risk perception caused by several factors, such as age and socio-economic status. AHP allowed to obtain the preference weights of the four analyzed factors in the vulnerability of the region, evidencing the higher importance of the "floods" factor in comparison to the others, and as a consequence the necessity or reorienting the efforts of developing practices and projects of risk reduction in the region.

Introduction

In the evaluation of natural and anthropic risks are applied different methods - qualitative, quantitative and hybrid – each with its advantages and inconvenients. Among them, the methods of the questionnaire and Analytic Hierarchy Process (AHP) allow evidencing the degree of exposure to hazards and also the assessment of factor weights in human communities' degree of vulnerability.

The method of the questionnaire or of the preferred preferences offers the possibility of a qualitative and quantitative interpretation through statistic methods and descriptive graphics.

The AHP method offers a matrix model of integrating, based on the systemic interpretation by pair-wise comparison of a list of factors, options or alternatives.

[1] Assoc. Prof. PhD., Alexandru Ioan Cuza University, Iaşi, adriangrozavu@yahoo.com
[2] PhD., Alexandru Ioan Cuza University, Iaşi, sergiuplescan@yahoo.com
[3] Lect. PhD., Alexandru Ioan Cuza University, Iaşi, margarint.ciprian@yahoo.com

Mathematically described by Saaty (1977, 1990), Saaty and Vargas (1984, 2001), it became one of the best known and most widely used multi-criteria decision-making method.

In the geographical studies in Romania the method is almost inexistent, although the range of reported practical applications is extensive (Vargas, 1990). Thus, AHP is considered an effective method for eliciting expert knowledge, making a useful tool for development of expert systems in natural resource management, where even expert knowledge is often incomplete (Reynolds and Holsten, 1994). A model to deal with a multicriteria group decision-making problem involving a set of feasible land-use options vas developed by Malczewski et al. (1997). AHP is proposed to address the need for considering multiple criteria and multiple stakeholders in Environmental Impact Assessment (EIA) (Ramanthan et al., 2001). Some of the authors argued that AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist (Millet and Wedley, 2002). Recently, the method started to be successfully applied also in geomorphologic risk assessment, especially in landslide susceptibility analysis (Ayalew et al., 2005; Komac, 2006).

The current paper focuses on the evaluation of the weights of the potential risk factors by interpreting and comparing the results obtained after applying the methods of the questionnaire and AHP. The study was applied to Lepşa-Greşu Depression, located in Vrancea Mountains from Eastern Carpathians, along Putna River and its tributaries Lepşa, Greşu and Strei, where in the last years is being felt an increasing pressure on natural space and, implicitly, a higher degree of exposure to different risks.

1.Methodology

The main steps and operations that we propose to be followed are: identification of potential hazards and of elements at risk from the study area, the evaluation of the natural risk factors through the application of the two mentioned methods (the questionnaire and AHP), and assessment of factor importance to region's degree of vulnerability.

Thus, field studies and investigations among the local population allowed the identification of the types of potential hazards present in the studied region:

- heavy rains, conditioned by certain particular synoptic conditions;
- flash floods, favored by the climatic conditions, hydrologic regime of rivers (with significant seasonal variations) and the morphology of riverbeds, with direct implications on the riverbed processes' manifestation;
- mass movements, especially active landslides and also with great activation potential, present on about 1,265 hectares, favored by geo-structural conditions,

lithological composition, relief fragmentation, active tectonics and often intensified by the anthropic factor;

- earthquakes (the studied area is situated in the vicinity of the Vrancea seismic area);
- uncontrolled anthropic interventions, especially overloading of slopes with dwellings and constructions in close proximity to rivers, contributing to the acceleration of risk phenomena and degradation of land quality;

Also have been identified basic elements at risk considering the potential risk phenomena:

- population: 404 inhabitants (Lepşa - 291 inhabitants; Greşu - 121 inhabitants), presenting a high ageing degree, according to the 2002 population census;
- buildings: 120 permanent residences of the local population (generally occupying positions which avoid the influences of natural risks) and 1124 secondary residences or buildings with touristic destination, occupying both spaces outside the risk influences area (close to the primary residences) but also spaces exposed to risks (terrains on high slopes, exposed to slope processes, floodplains);
- communication network, infrastructure: many roads' sectors and/or other economic objectives are susceptible to being affected by landslides, rock falls, floods etc.

In what regards the methods chosen for the analysis, **the questionnaire** and implicitly the results of its application on a population sample form the study area have already been discussed in a previous paper (Grozavu and Pleşcan, 2010). From the 11 questions of the questionnaire, relevant for the present study are the 2nd and 3rd questions, by attempting to understand the perception by the population on the probability of risk phenomena and on their intensity, in other words the risk awareness of the population:

Question no. 2: **Do you think you live in an area that may be affected by dangerous natural phenomena?** Grades from 1 to 5 (1 = very low probability, ... 5 = very high probability of producing phenomenon):

heavy rains__; flash floods__; landslides__; earthquakes__; other__;

Question no. 3: **Of these phenomena which one do you think would represent the higher risk?** Grades from 1 to 5 (1 = low risk, ... 5 = very high risk):

heavy rains__; flash floods__; landslides__; earthquakes__; other__;

Data processing has been done by quantitative and qualitative methods of interpretation and statistical method (descriptive graphics).

Regarding the ***AHP method***, it is known that it is a semi-qualitative one, implying operations of normalization, synthesis and ordination of alternative options. Basically, this approach involves the construction of a pair-wise comparison matrix where each factor is rated against every other factor by means of predefined scores (from 1 to 9) indicating their relative importance (tab. 1). In other words, the weights and scores are achieved basically by pair-wise comparisons between all options with each other.

Tab. 1 - Scale of preference between two parameters in AHP (Saaty, 1977)

Scales	Degree of preferences	Explanation
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2,4,6,8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9
Reciprocals	Opposites	Used for inverse comparison

Then the weights of each factor are derived by extracting the principal eigenvector from the pair-wise comparison matrix. The method also explicitly evidences the inconsistency or incongruence between comparative pair judgments (the detailed procedure for testing inconsistency was also constructed by Saaty).

In the present study the method has been applied by taking into consideration the same four factors (or potential risk phenomena) identified in the study region.

2.Results and discussion

The interpretation of the answers to the two questions of the questionnaire reveals a weak and diffuse perception on the probability of the occurrence and on the intensity of the risk phenomena along the population from the Lepşa-Greşu depression (Grozavu and Pleşcan, 2010).

Also, inferential statistics has tried to evidence the correlations between different factors by computing the correlation index R^2 applying the exponent function. Thus, regarding the perception of the occurrence probability of risk phenomena, the best correlations are achieved between the age of those who responded on one hand, and landslides (R^2 = 0.501) and heavy rains (R^2 = 0.452) on the other hand, while for the perception of the risk phenomena intensity the best correlations are achieved between the educational level of respondents and landslides (R^2 = 0.586), respectively, heavy rains (R^2 = 0.225). Good correlations are also established between respondent's age and earthquakes (R^2 = 0.681). These have led to a valuable conclusion: the age and level of education are parameters that can be followed in future studies on risk perception phenomena.

By applying the AHP method, since we have four parameters, has been constructed a comparison matrix containing sixteen boxes. The selection of the appropriate scores was guided by site characteristics (tab. 2).

Tab. 2 - The pair-wise comparison matrix and the relative importance of each factor in relation to the others

Factors	Flash floods	Mass movements	Earthquakes	Heavy rains
Flash floods	1	3	5	5
Mass movements	1/3	1	3	4
Earthquakes	1/5	1/3	1	3
Heavy rains	1/5	1/4	1/3	1

Then the method implied the normalization of the values (by summing up on each column and dividing the sum to each value), and then computing the sum on each row and finally calculating the factor weights (by dividing the sum of each row to 4) (tab. 3).

Tab. 3 - Normalized values and factor weights

Factors	Flash floods	Mass movements	Earthquakes	Heavy rains	**Weight**
Flash floods	0.577	0.655	0.536	0.385	**0.538**
Mass movements	0.192	0.218	0.321	0.308	**0.260**
Earthquakes	0.115	0.073	0.107	0.231	**0.131**
Heavy rains	0.115	0.054	0.036	0.077	**0.071**

It can be noticed that the weight corresponding to the four factors varies between 0.538 (flash floods) and 0.071 (heavy rains). The highest value obtained for 'flash floods' factor is confirmed by site characteristics and by statistics regarding the inventory of these phenomena in the area. The relatively high weight of ‘mass movements’ is explained by the fact that numerous road sectors in the area are already affected or threatened by such processes, while the low weights of ‘earthquakes’ and ‘heavy rains’ factors can be connected with nonlinearity manifestation of these phenomena.

In order to check the discordances between the pair-wise comparisons and the reliability of the obtained weights, one must further compute the *consistency ratio (CR)*. In AHP, the consistency used to build a matrix is checked by a consistency ratio, which depends on the number of parameters. For a 4 x 4 matrix (as it is in the present case), the consistency ratio must be less than 0.1 to accept the computed weights, otherwise it is necessary to review the subjective judgement (Saaty and Vargas, 2001).

For computing the consistency ratio (CR), the following formula was applied:

$$CR = \frac{CI}{RI} \quad (1)$$

where CI represents the *consistency index*, computed according:

$$CI = \frac{\lambda \max - n}{n - 1} \quad (2)$$

where λ *max* represents the sum of the products between the sum of each column of the comparison matrix and the relative weights obtained, and *n* represents the size of the matrix (in our case 4).

RI is *the random consistency index*, being already computed by Saaty from a sample of 500 matrixes randomly generated (for a matrix of size 4 the computed value is of 0.9).

The introduction into the formulas of the values obtained led to the following result:

$$CR = \frac{\frac{\lambda \max - n}{n - 1}}{0.9} = \frac{\frac{4.266 - 4}{4 - 1}}{0.9} = \frac{0.089}{0.9} = 0.098 \quad (3)$$

Because the values is smaller than 0.1, the inconsistency is acceptable, indicating the adequate degree of consistency used to construct the comparison matrix.

Conclusions

The methods of the questionnaire and AHP allow evidencing the exposure degree to hazards and also the assessment of factor weights in human community’s degree of vulnerability.

The application of the questionnaire reveals a weak and diffuse perception on the risk phenomena among the population of Lepşa-Greşu depression, which imposes convergent measures for the education of the population so as to raise the awareness to risks and face the eventual extreme natural phenomena. Also, the analysis evidenced the fact that in risk perception there are correlations and variations caused by several factors, such as age and socio-economic status.

AHP may be a very effective tool for objective hierarchy. In the present case it proved to be useful in obtaining the preference weights of the four analyzed factors in the vulnerability of the region. In this way has been evidenced the higher importance of the "flood" factor in comparison to the other factors in the vulnerability of the region. In this direction should be reoriented the efforts of local authorities and decision-makers for developing practices and projects for risk reduction in the region.

References:

Ayalew L., Yamagishi H., Marui H., Kanno T. (2005), *Landslides in Sado Island of Japan: Part II. GIS-based susceptibility mapping with comparisons of results from two methods and verifications.* Engineering Geology, 81, pp. 432– 445.

Grozavu, A., Pleşcan, S. (2010), *The natural risks perception in Lepşa-Greşu Depression*. Present Environment and Sustainable Development, 4, pp. 199-210.

Komac M. (2006), *A landslide susceptibility model using the Analytical Hierarchy Process method and multivariate statistics in perialpine Slovenia*. Geomorphology, 74, pp. 17–28.

Malczewski, J., Moreno-Sanchez, R., Bojorquez-Tapia, L. A. and Ongay-Delhumeau, E. (1997), *Multicriteria group decision-making model for environmental conflict in the analysis in the Cape Region, Mexico*. Journal of Environmental Planning and Management, 40(3), pp. 349-374.

Millet, I., Wedley, W. C. (2002), *Modelling Risk and Uncertainty with the Analytic Hierarchy Process*. Journal of Multi-Criteria Decision Analysis, 11, pp. 97−107.

Ramanathan R. (2001), *A note on the use of the Analytic Hierarchy Process for environmental impact assessment*. Journal of Environmental Management, 63, pp. 27−35.

Reynolds K. M., Holsten E. H. (1994), *Relative importance of risk factors for spruce beetle outbreaks*. Canadian Journal of Forest Research, 24(1), pp. 2089-2095.

Saaty T. (1977), *A scaling method for priorities in Hierarchical Structures.* Mathematical Psychology, 15, pp. 234-281.

Saaty T. (1990), *How to make a decision: The Analytic Hierarchy Process*. European Journal of Operational Research, 48, pp. 9−26

Saaty T., Vargas L. G., (1984), *Inconsistency and Rank Preservation.* Journal of Mathematical Psychology, 28, pp. 205-214.

Saaty T., Vargas L. G. (2001), *Models, Methods, Concepts, and Applications of the Analytic Hierarchy Process*. Kluwer Academic Publisher, Boston.

Vargas L. G. (1990), *An overview of the Analytic Hierarchy Process and its applications.* European Journal of Operational Research, 48, pp. 2-8.