WEIGHTS DETERMINATION IN MCDM MODEL COMBINING THE TECHNIQUES OF MATHEMATICAL AND STATISTICAL ANALYSIS

[1]Dragan RANDJELOVIĆ,[2] Jasmina JANJIĆ,[3]Jelena STANKOVIĆ,[4] Milan RANDJELOVIĆ, [3]Milivoje PEŠIĆ

[1]The Academy of Criminalistics and Police Studies Belgrade, [2]University of Priština, Faculty of Agriculture Lešak, [3]University of Niš, Faculty of Economics, [4]Economic Development Office- City of Niš

Key words: AHP, Spearman Coefficients, Criteria Weights, Business Friendly Certification, FDI

Assoc. Prof. Ph. D. Eng. Dragan RANDJELOVIĆ

Ass. Mr. Jasmina JANJIĆ

Assist. Prof. Ph. D. ecc. Jelena STANKOVIĆ

Mr Milan Randjelovic

Assoc. Prof. Ph. D. ecc. Milivije PEŠIĆ

Abstract: *Determining the weights is one of the most important issues in multiple criteria decision-making models (MCDM models) and their applications. Precisely from that reason it has been developed a number of methodologies based on statistical and mathematical analyses. All these methodologies are used to quantify the preferences of decision-makers, as well as to give an objective evaluation of the criteria's relative importance based on available data. The aim of this paper is combining these two approaches for determination weights in multi-criteria model of contemporary problem of Serbian economy such is business friendly certification of local self-government units.*

1. INTRODUCTION

Business Friendly Certification (BFC) of local self-government units (LSGU) is a process that promotes standards for efficient and transparent administration and allows evaluation of the quality of services and information for investors and businessmen. It is a process which aims to improving the economic climate of Serbia through institutional reforms with active participation and cooperation of industry, municipalities and citizens. Therefore, this process involves the review and evaluation of various criteria while longer, which in terms of optimization techniques allows the use of multi-criteria methods and models. One of the key issues of multi-criteria analysis, just after establishment of an adequate model, is determining the importance of all criteria that are considered relevant in this model. Weighs have a significant influence on the final outcome of decision making and that's why it is necessary to determine them properly.

All methods for determining the weights can be classified into two main groups - the subjective and objective methods. Subjective methods are related to a set of methods that respects greatly subjective preferences of the decision maker in the process of evaluation criteria relevant. In this group are belonging following methods: Analytic hierarchy process (AHP method), Delphi method, Weighted least squares method and Conjoint analysis, according to [1] and [2].

Objective methods, on the other hand, are concerned with weight coefficient assignment on the basis of analysis of data on the problem, not taking into account the attitude of decision-makers. Some of the most common objective methods are entropy, principal component method, regression analysis, correlation analysis, data envelopment analysis, spearman correlation, etc. [3].

Starting from the general model of multi-criteria analysis in which it is necessary to evaluate one of the m alternatives (A_i, i=1,2,…,m), in accordance with n different relevant criteria (C_j, j=1,2,…,n), the importance of each criterion C_j is determined by the weight coefficients w_j. Regardless of method for their calculation or determination, all relative weight in MCDM model must meet the following requirements: (1) $0 \leq w_j \leq 1$ and (2) $\sum_{j=1}^{n} w_j = 1$.

2. BACKGROUND INFORMATION

The BFC procedure is carried out actively in Serbia in the last five years by National Alliance for Local Economic Development (*NALED*) and the results are very concrete and have positive implications on business environment. Almost a third of all local self-government units in Serbia are improving their economic environment through this program of certification. Criteria for certification provide clear guidance to LSGUs on the type and quality of services, information and infrastructure that investors and businessmen expect. Each city or municipality included in the certification process receives specific recommendations for reforms that are necessary to carry out in order to create a favourable business environment that includes the efficient administration, transparent local governance, adequate infrastructure and partnership with the business sector. BFC process encompasses a range of activities that can be schematically represented as in Figure 1.

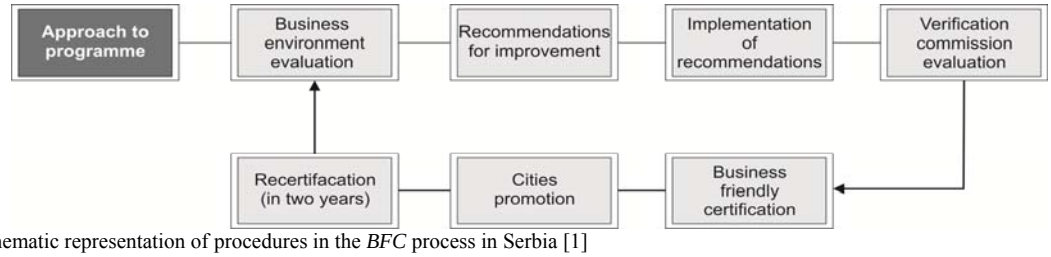

Figure 1 Schematic representation of procedures in the *BFC* process in Serbia [1]

The ultimate goal of certification is to strengthen the competitiveness of local governments, as well as investment promotion, increasing employment and raising living standards in Serbia. Certification Programme includes 12 criteria and over 80 sub-criteria by which is assessed whether and to what extent a municipality meets the standards of a friendly business environment [4]: (C1) Strategic planning of local economic development in partnership with businesses; (C2) Special department in charge of *LED*, *FDI* promotion and business support - *LED* Office; (C3) Business council for economic issues – advisory body to the mayor and local governments; (C4) Efficient and transparent system for acquiring construction permits; (C5) Economic data and information relevant for starting and developing a business; (C6) Multilingual marketing materials and website; (C7) Balanced structure of budget revenues / debt management; (C8)Investing into the development of local workforce; (C9) Cooperation and joint projects with local business on fostering *LED*; (C10) Adequate infrastructure and reliable communal services; (C11) Transparent policies on local taxes and incentives for doing business and (C12) Electronic communication and on-line services .

Assessing fulfillment of the criteria for certification and collecting additional information in cooperation with the municipality and the business community is done through the following set of steps: (i) Assessment of the existence of certain functions; (ii)Assessing the quality of services in the municipality; (iii) Assessing the quality and accuracy of data; (iv) Assessment of the status of each individual indicator; (v) Preparation of reports, comments and recommendations and (vi) Define additional requirements which are necessary for a positive evaluation and the fulfillment of the criteria.

Evaluation process is conducted in two stages: assessment of compliance with sub-criteria, in the first resort, and then assessment compliance with the criteria. The second level of evaluation is the average rating of all sub-criteria, which are defined criteria. Also, using the two-level evaluation is defined and the importance of each criterion. At the level of sub-criteria are defined by three levels of importance as follows: elimination - score two relevance, very influential - from a significant and important - relevance score 0.5.

The importance of the criteria, according to *NALED* is defined as the average score of the previous level of evaluation and as such can be called the relative importance of observed criteria C_j (row named *NALED's evaluation of criteria importance* in Table 1). As well as the data about level of fulfillment for all observed criteria are given in Table 1.

Table 1 The level of criteria fulfillment in municipalities surveyed according to *BFC* program

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	*Average*
NALED's evaluation of criteria importance	1.250	0.900	0.670	1.190	0.660	0.710	1.000	0.750	1.080	1.210	1.500	0.830	
LSGU 1	0.80	1.00	1.00	0.73	0.88	1.00	1.00	0.73	0.64	0.83	1.00	1.00	0.88
LSGU 2	0.63	0.95	0.80	0.94	0.86	1.18	0.90	0.75	0.67	0.94	0.93	1.00	0.88
LSGU 3	0.90	0.82	0.88	1.00	0.95	1.00	1.00	0.70	0.68	0.76	1.00	0.75	0.87
LSGU 4	1.00	0.62	1.00	0.78	0.60	0.67	1.00	0.60	0.59	0.98	0.83	1.00	0.81
LSGU 5	1.00	1.00	0.75	0.94	0.90	0.94	1.00	0.87	0.91	0.79	1.00	1.00	0.93

Using the data presented in Table 1 below in the paper are applied two different methods - AHP method as a mathematical, subjective approach to determining weight and Spearman correlations as statistically, objective approach to determining the weights.

3. WEIGHTS DETERMINATION USING AHP

AHP is a multi-criteria analysis method that provides a scientific basis for decision making problems and has been widely applied to both cases - when the decision maker is either individual or group, since the early 1980s, [5] and [6]. *AHP* is quantitative technique that has been used in almost all problems related to multi-criteria decision making and its application includes more than 150 different kinds of areas [7]. AHP method is a method for formulating and analysing decisions that can successfully be used to measure the influence of many factors relevant to the possible outcomes of decisions as well as for forecasting ie performance of relative probability distribution of outcomes.

According to Saaty [8], the AHP algorithm is based on three principles:

i. decomposition of the goal-value structure where a hierarchy of criteria, sub-criteria, and alternatives is developed, with the number of levels determined by the problem characteristics;
ii. comparative judgments of the criteria on single pair-wise comparisons of such criteria with respect to an upper criteria; and
iii. linear-based synthesis of priorities where alternatives are evaluated in pairs with respect to the criteria on the next level of the hierarchy, and criteria can be given a priority (e.g. preference) expressed as a weight in the AHP matrix.

At the first level, the problem is decomposed in hierarchical structure, where the goal is on the top, while the criteria by which a decision is made are treated at the lower levels. At the lowest hierarchical level is a range of alternatives, which comparisons is necessary to make. The hierarchical structure of BFC problem for evaluation of LSGU is given in Figure 2.

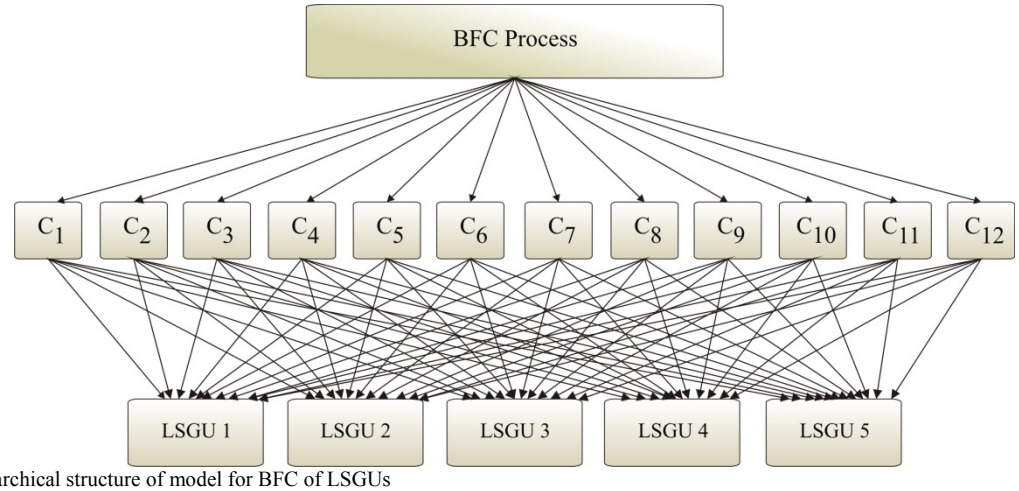

Figure 2 Hierarchical structure of model for BFC of LSGUs

The next phase involves, first of all, pair-wise comparison of criteria and alternatives at a given level of hierarchy, but also in relation to the criteria of the directly higher level. Pairwise comparison of alternatives is done in response to the question of which of the two observed attributes that characterize an alternative to the given criteria, is better in terms of meeting the criteria and contribution to the certain objective. Strength of preference is expressed by the ratio scale with increments of 1-9. The preferential level of 1 shows equality of observed attributes, while the level of 9 indicates absolute, the strongest preference of one attribute over another [9] and [10].

Such a scale was formed by Saaty [6] and it is used in essential AHP method and for its entire later advanced variant (Analytic Network Process - ANP) [11]. Thus, defined scale allows comparisons in a limited scope, while the perception is a sensitive enough to make a difference in the alternatives importance. In this particular problem, which is discussed in this paper, is necessary to perform comparison on the level of criteria in order to determine the weights of the MCDM model.

On the basis on pair-wise comparison, reciprocal matrix is formulated (Table 2). Based on the pare-wise comparison, reciprocal matrix and algorithm of AHP method, it is calculated vector of priorities has been calculated, as it is shown in Figure 3.

Table 2 Pare-wise comparison of criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
C_1	1	4	8	1	8	7	3	6	2	1	1/3	5
C_2	1/4	1	4	1/4	4	4	1/2	3	1/3	1/4	1/6	2
C_3	1/8	1/4	1	1/7	1	1	1/5	1/2	1/6	1/7	1/9	1/3
C_4	1	4	7	1	7	6	3	6	2	1	1/3	5
C_5	1/8	1/4	1	1/7	1	1/2	1/5	1/2	1/6	1/7	1/9	1/3
C_6	1/7	1/4	1	1/6	2	1	1/4	1	1/5	1/6	1/9	1/3
C_7	1/3	2	5	1/3	5	4	1	4	1/2	1/3	1/5	3
C_8	1/6	1/3	2	1/6	2	1	1/4	1	1/2	1/6	1/8	1/2
C_9	1/2	3	6	1/2	6	5	2	2	1	1/2	1/4	4
C_{10}	1	4	7	1	7	6	3	6	2	1	1/3	5
C_{11}	3	6	9	3	9	9	5	8	4	3	1	7
C_{12}	1/5	1/2	3	1/5	3	3	1/3	2	1/4	1/5	1/7	1

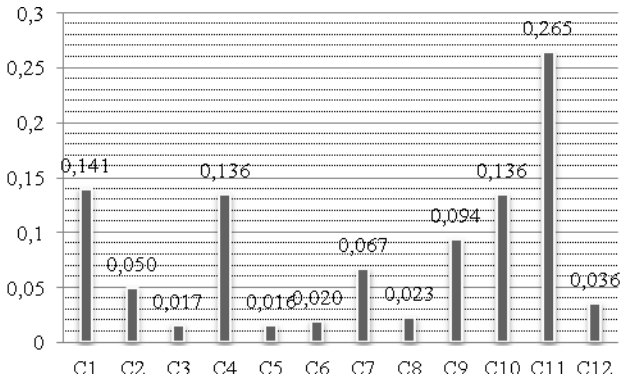

Figure 3 The estimated significance of the criteria for Business Friendly Certification

4. WEIGHTS DETERMINATION USING SPEARMAN COEFFICIENTS

One of known taxonomy of statistic techniques in literature is on the research relations between variables and research differences between groups. First of mentioned group of techniques and methods can be used for determining the weights of criterions in different models. In this group belong correlation and partial correlation, multiple regression, factor and discrimination analysis etc. Unfortunately some of given methods which are applicable on continued variables (like Pearson correlation, regression and factor analysis) demand very strong conditions for possible application first of all normal distribution of considered independent variables i.e. criterion than in the relations between number of independent variables i.e. criterions in considered case and the size of the sample what means obviously big number of units in the sample etc. Others are applicable only on categorical dependent variables as for example discrimination analysis and Chi-square test [12], [13] and [14]. When calculating a correlation coefficient for ordinal data, one should select Spearman's technique, according to [15, pg 669].

As one taxonomy of statistic techniques exists division on parametric and non-parametric methods. Each of parametric technique must satisfies additional strong conditions first of all normal distribution of considered independent variables than a relations between number of independent variables and the number of noticed units in considered sample etc. what is different for different methods. Non-parametric methods also demands some soft conditions; they are applicable when suitable parametric methods don't satisfy necessary conditions. It is important that non-parametric methods have one evident disadvantage in relation with mentioned parametric techniques and that is minor sensitivity and because of that lesser precision of detecting difference between considered groups i.e. influence between variables depend of enforced of mentioned type of statistic research in the beginning of this section. Having in mind the number of units in considered study of five cities in Serbia and twelve criterions which influence on scale of goodness for investment we determine in this study we must choose Spearman's correlation as a statistic method to determine the weights of criterions in the model for certification cities.

Using SPSS 17.0.0 application of Spearman correlation method authors obtain results which are given in Table 3.

Table 3 Spearmans parameters rho results for the relevant criteria in the observed cities

Spearman's rho		VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006	VAR00007	VAR00008	VAR00009	VAR00010	VAR00011	VAR00012	VAR00013
VAR00001	rho	1,000	-,237	-,026	-,154	,051	-,947*	,725	-,205	,103	-,051	-,057	,459	-,103
	Sig.	.	,701	,966	,805	,935	,014	,165	,741	,870	,935	,927	,437	,870
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00002	rho	-,237	1,000	-,395	-,308	,359	,289	,000	,821	,462	-,359	,688	,344	,975**
	Sig.	,701	.	,511	,614	,553	,637	1,000	,089	,434	,553	,199	,571	,005
	N	5	5	5	5	5	5	5	5	5	5	5	5	5

VAR00003	rho	-,026	-,395	1,000	-,564	-,410	-,237	,363	-,821	-,872	,410	-,287	,229	-,564
	Sig.	,966	,511	.	,322	,493	,701	,548	,089	,054	,493	,640	,710	,322
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00004	rho	-,154	-,308	-,564	1,000	,500	,410	-,354	,100	,600	-,500	,112	-,894*	-,200
	Sig.	,805	,614	,322	.	,391	,493	,559	,873	,285	,391	,858	,041	,747
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00005	rho	,051	,359	-,410	,500	1,000	,205	,354	,300	,800	1,000**	,894*	-,447	,400
	Sig.	,935	,553	,493	,391	.	,741	,559	,624	,104	.	,041	,450	,505
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00006	rho	-,947*	,289	-,237	,410	,205	1,000	-,725	,359	,205	-,205	,229	-,631	,205
	Sig.	,014	,637	,701	,493	,741	.	,165	,553	,741	,741	,710	,254	,741
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00007	rho	,725	,000	,363	-,354	,354	-,725	1,000	-,354	,000	-,354	,395	,395	,000
	Sig.	,165	1,000	,548	,559	,559	,165	.	,559	1,000	,559	,510	,510	1,000
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00008	rho	-,205	,821	-,821	,100	,300	,359	-,354	1,000	,700	-,300	,447	,112	,900*
	Sig.	,741	,089	,089	,873	,624	,553	,559	.	,188	,624	,450	,858	,037
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00009	rho	,103	,462	-,872	,600	,800	,205	,000	,700	1,000	-,800	,671	-,335	,600
	Sig.	,870	,434	,054	,285	,104	,741	1,000	,188	.	,104	,215	,581	,285
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00010	rho	-,051	-,359	,410	-,500	1,000**	-,205	-,354	-,300	-,800	1,000	-,894*	,447	-,400
	Sig.	,935	,553	,493	,391	.	,741	,559	,624	,104	.	,041	,450	,505
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00011	rho	-,057	,688	-,287	,112	,894*	,229	,395	,447	,671	-,894*	1,000	-,125	,671
	Sig.	,927	,199	,640	,858	,041	,710	,510	,450	,215	,041	.	,841	,215
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00012	rho	,459	,344	,229	-,894*	-,447	-,631	,395	,112	-,335	,447	-,125	1,000	,335
	Sig.	,437	,571	,710	,041	,450	,254	,510	,858	,581	,450	,841	.	,581
	N	5	5	5	5	5	5	5	5	5	5	5	5	5
VAR00013	rho	-,103	,975**	-,564	-,200	,400	,205	,000	,900*	,600	-,400	,671	,335	1,000
	Sig.	,870	,005	,322	,747	,505	,741	1,000	,037	,285	,505	,215	,581	.
	N	5	5	5	5	5	5	5	5	5	5	5	5	5

Variable notated with VAR13 in given Table 3 is independent variable of investments in considered LSGU (Table 4), according to [16].

Using the normalization of obtained *Spearman* parameters, it could be calculated relative weights of all criteria according to demands of multi-criteria models, as it is already described (Table 5).

Table 4 Total investments in LSGU

LSGUs	Total Investments in 2011 **	%
LSGU 1	4,163,364.00	30.15%
LSGU 2	1,770,640.00	12.82%
LSGU 3	1,504,476.00	10.89%
LSGU 4	1,212,435.00	8.78%
LSGU 5	5,160,093.00	37.36%

**The official figure is expressed in RSD noting that the parity of the exchange €, at the time of writing of this paper 1 € = 115RSD

Table 5 The importance of the criteria established in accordance with the Spearman parameters

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
Spearman Parameters	**-,103**	**,975****	**-,564**	**-,200**	**,400**	**,205**	**,000**	**,900***	**,600**	**-,400**	**,671**	**,335**
Relative Weights (ω_i^*)	**0.019**	**0.182**	**0.105**	**0.06**	**0.075**	**0.038**	**0**	**0.168**	**0.112**	**0.075**	**0.125**	**0.063**

The difference in the results that are observed by comparing Figure 3 and Table 5 was created as a consequence of the fact that in the first results from Figure 2, in evaluating the significance, do not included achieving a certain level of criteria, but the score was performed on the basis of previous experience on the importance of sub-criteria. Inclusion of additional information provides the solution at a higher level of credibility which represents the real situation at a time, for the observed level of fulfillment of the criteria in the cities who have received certificates of favorable business environment.

5. COMBINING APPROACH OF AHP METHOD AND SPEARMAN COEFFICIENTS FOR WEIGHTS DETERMINATION

Combining approach involves the calculation of integrated weights. Weights are obtained as the arithmetic mean of the weights being determined by the procedure explained above, using subjective and objective methods. The integrated results are presented in Table 6.

Table 6 Weights established in accordance with the combining approach of AHP and Spearman parameters

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
Using AHP	0.141	0.050	0.017	0.136	0.016	0.020	0.067	0.023	0.094	0.136	0.265	0.036
Using Spearman Parameters	0.019	0.182	0.105	0.06	0.075	0.038	0	0.168	0.112	0.075	0.125	0.063
Combining Approach	**0.080**	**0.116**	**0.061**	**0.098**	**0.046**	**0.029**	**0.034**	**0.096**	**0.103**	**0.106**	**0.195**	**0.050**

6. CONCLUSION

This paper proposes a combining approach of subjective and objective methods to determine attribute weights. Subjective approach to determination of weights involves a high level of respect for the decision-maker preferences. Thus, the weights determined using AHP method is based solely on the subjective perception of NALED, as a body which deals with the process of BFC. On the other hand, by calculating the Spearman coefficient, rank correlation is determined by the level of compliance with the specified criteria in the respective LSGU and the amount of investment that has generated in this LSGU. Combining approach provides the ability to determine the weights that include both of these components, which contributes to the quality of the model and the reliability of a decision.

**This paper was supported by the Ministry of Education and Science of the Republic of Serbia (Projects no. 44007, TR 34019)*

6. REFERENCES

[1] A. Čupić, M. Blagojević, D. Marković: *Combined Approach in Weight Coefficient Assignment for Technical System Selecting*, Tehnička dijagnostika, Vol. 6, No. 4, (2007), pages 33-38, ISSN: 1451-1975.

[2] J. Ma, Z. Fan and L. Huang: *A Subjective and Objective Integrated Approach to Determine Attribute Weights,* European Journal of Operational Research, Vol. 112, No. 2, (January, 1999), pages 397-404, ISSN: 0377-2217.

[3] F. Maggino, E. Ruviglioni: *Obtaining weights: from objective to subjective approaches in view of more participative methods in the construction of composite indicators*, http://epp.eurostat.ec.europa.eu/portal/page/portal/research_methodology/documents/POSTER_1A_OBTAINING_WEIGHTS_MAGGINO_RUVIGLIONI.pdf

[4] *http://www.naled-serbia.org/*

[5] T.L. Saaty, L. Vargas, Decision making in economic, political, social, and technological environments with the analytic hierarchy process, Volume 7 of The Analytic hierarchy process series. RWS Publications, Pittsburgh, 1994. ISBN 0962031771

[6] Y. Wind, T.L. Saaty, "Marketing applications of the analytic hierarchy process", Management Sciences, Vol. 26, No. 7, pp. 641–658 1980, ISSN: 0025-1909

[7] V. Omkarprasad, S. Kumar, "Analytic hierarchy process: An overview of applications", European Journal of Operational Research, Vol. 169, pp. 1–29 2006. ISSN: 0377-2217.

[8] T.L. Saaty, "A scaling method for priorities in hierarchical structures", Journal of Mathematical Psychology, 15, pp. 234-281 1977.

[9] J. Ma, Q. Zhang, , 9/9-9/1 scale method of the AHP, Proceedings of 2nd International Symposium on the AHP 1: 197-202 1991.

[10] P. Leskinen, "Measurement scales and scale independence in the Analytic Hierarchy Process", Journal of Multi–Criteria Decision Analysis, Volume 9, pp. 163–174 2000.

[11] P. Mimović, M. Kocić and M. Milanović (2012) A'WOT model in selecting the optimal tourism development strategy in Vrnjacka Banja, Teme 2/2012, pp 815-836, ISSN 0353-7919

[12] J. Pallant, SPSS Survival Manual:A step by Step Guide to Data Analysis using SPSS for Windows,(2007) Allen&Unwin

[13] B.G. Tabachnick& L.S. Fidell, Using multivariate statistics,(2007)Pearson Education

[14] W. Daniel, Applied nonparametric statistics,(1990) PWS-Kent

[15] M. Anđelković, V. Janković-Milić, B. Bojić. "Improvement of competitiveness at high education market – case study", TTEM - Technics Technologies Education Management, DRUNPP Sarajevo, 2011, Vol. 6, No. 3, pg.663-672, ISSN 1840-1503

[16] Statistical Office of the Republic of Serbia " Municipalities and Regions in the Republic of Serbia, 2011", http://webrzs.stat.gov.rs /WebSite/repository/documents/00/00/54/08/Opstinski_godisnjak_Republike_Srbije_2011.zip

Correspondence to:

Dragan RANĐELOVIĆ
dragan.randjelovic@kpa.edu.rs, University of Belgrade, The Academy of Criminalistics and Police Studies,

Jasmina JANJIĆ
Mina1@ptt.rs, University of Pristina, The Faculty of Agriculture

Jelena STANKOVIĆ
jelena.stankovic@eknfak.ni.ac.rs, University of Niš, Faculty of Economics,

Milan RANDJELOVIĆ
Magis80@gmail.com, Local Economic Development Office- City of Niš

Milivoje PEŠIĆ
milivoje.pesic@eknfak.ni.ac.rs, University of Niš, Faculty of Economics.