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THE INTEGRATED APPLICATION OF THE AHP AND THE DEA METHODS IN EVALUATING THE PERFORMANCES OF HIGHER EDUCATION INSTITUTIONS IN THE REPUBLIC OF SERBIA

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The measurement and evaluation of performance are critical for the efficient and effective functioning of the economic system, because this allows for the analysis of the extent to which the defined objectives are achieved. Organizational performance is measured by different methods, both quantitative and qualitative. Many of the known methods for the evaluation and measurement of organizational performance take into account only financial indicators, while ignoring the non-financial ones. The integration of both indicators, through the combined application of multiple methods and the comparison of their results, should provide a more complete and objective picture of organizational performance. The Analytic Hierarchy Process (AHP) is a formal framework for solving complex decision-making problems, as well as a systemic procedure for the hierarchical presentation of the problem elements. The Data Envelopment Analysis (DEA) is a non-parametric approach based on linear programming, which allows for the calculation of the efficiency of decision-making units within a group of organizations. The work is an illustration of the method and framework of the combined use of the multi-criteria analysis methods for the measurement and evaluation of the performance of higher education institutions in the Republic of Serbia. The advantages of this approach are reflected in overcoming the shortcomings of a partial application of the AHP and the DEA methods by utilizing a new, hybrid, DEAHP (Data Envelopment Analytic Hierarchy Process) method. Performance evaluation through an integrated application of the AHP and the DEA methods provides more objective results and more reliable solutions to the observed problem, thus creating a valuable information base for high-quality strategic decision making in higher education institutions, both at the national level and at the level of individual institutions.

Keywords: multi-criteria analysis, analytic hierarchy process, data envelopment analysis, organizational performance, higher education

JEL Classification: C44, C61, D81, I23

INTRODUCTION

The evaluation of organizational performance is one of the most important activities for all managers

and stakeholders. As a tool allowing them to assess organizational strengths and weaknesses, as well as a competitive advantage over the competition, the evaluation of organizational performance creates conditions for defining the guidelines and selecting the measures that must be taken in order to overcome the existing problems.

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Organizational performance is, in general, multidimensional and influenced by a number of factors, such as financial factors, as the indicators of the financial position of the organization, strategic qualitative factors, which determine the internal activities of the organization and their relationship with the market and economic factors, including the business environment, etc. The aggregation of all these factors into a composite, overall performance measure is a subjective and complex process depending on the value and preference systems of decision makers in the decision-making process. Creating a performance measurement system is, therefore, a complex task, and what is to be considered as an optimal performance measurement system will vary from one case to another (Tangen, 2005). In this regard, it is important to understand how performance measurement systems are developed and integrated into organizations' management models. These findings are fully consistent with the basic multi-criteria decision-making paradigm, which has resulted in numerous studies of the possibilities of the application of multi-criteria decision making in the process of measuring and evaluating organizational performance (Aruldoss, Lakshmi & Venkatesan, 2013).

As a result of the Bologna Process, internationalization and the introduction of private colleges and universities, higher education institutions are exposed to greater competition. There is a continuing need for comparing different educational institutions, so that those wanting to enroll in the faculty could opt for the best one under the observed criteria. The aim of the ranking is to establish transparency and make information about universities useful for multiple target groups, such as high-school graduates, their parents, university professors, university managers, ministries and employers. Numerous studies show that university ranking influences the selection of faculties/universities on the part of students who finish school. G. Saad (2001) notes that performance analysis allows for an efficient and effective allocation of available resources. It also allows higher education planners to identify universities with the highest level of performance.

The subject of the research is measuring the performance of higher education institutions in the Republic of Serbia (RS). Although awaited for a long time, the evaluation and ranking of the universities and faculties in RS have not been formally conducted, nor have criteria and the manner in which the ranking will be carried out been determined. In this regard, based on the case of the twelve faculties within the four state universities in the Republic of Serbia (Belgrade, Novi Sad, Nis, and Kragujevac), a new approach to their evaluation and ranking for the academic year 2013/2014 is proposed here, which eliminates arbitrariness and partiality.

The objective of the paper is to improve the performance evaluation process in higher education institutions in the Republic of Serbia based on the combined and integrated use of multi-criteria decision-making methods.

In accordance with the set objective and the subject of research, the starting hypothesis has been formulated:

H: The application of the hybrid Data Envelopment Analytic Hierarchy Process (DEAHP) method, through the synergistic effect of the combined use of the Analytic Hierarchy Process (AHP) and the Data Envelopment Analysis (DEA) methods, results in a formal, scientifically based framework for the evaluation of the performance of higher education institutions, thus creating assumptions for their objective and efficient ranking.

To this end, the work is structured as follows: first, a brief theoretical overview of the issue and the most important aspects of organizational performance measurement are provided. Then, the literature review points to the most important references dealing with the implementation of the AHP and the DEA methods in higher education institutions, after which the methods used in this work are briefly explained - the AHP, the DEA and the DEAHP. Based on the measurement of the efficiency and ranking of the twelve selected faculties in the Republic of Serbia, the last part of the paper shows that the combined use of these methods results in a comprehensive and

objective evaluation of the performance of the faculties observed.

THE LITERATURE REVIEW

In practice, multi-criteria analysis has proven to be a suitable theoretical and methodological instrument for covering and solving numerous decision-making problems, both in companies and non-profit organizations. The diverse nature of the factors influencing the decision-making process, the complexity of the business and the economic environments, and the subjective nature of a number of decisions are just some of the characteristics of financial decisions enabling the implementation of a multi-criteria methodological framework. The need for the simultaneous observation of multiple criteria, including decision makers' personal preferences, is an important management component. The application of multi-criteria decision making allows the decision maker (the manager) to actively participate in the decision-making process and helps them understand and deal with complexity and uncertainty as the characteristics of the business environment. This means that their role is not reduced to the passive implementation of an optimal solution (if any) resulting from the multi-criteria model applied, but rather that they actively participate in the process of problem structuring and modelling, as well as in the analysis, interpretation and implementation of the results obtained. Multi-criteria decision making can be said to provide a wide array of techniques for the synthesis of the multiple criteria used in performance measurement, with the aim of selecting, ranking, classifying and describing a set of alternative options, as numerous scientific and professional studies have proven.

Multi-criteria decision-making techniques, such as the Analytic Hierarchy Process, the Analytic Network Process, TOPSIS and others, have been extensively used in the measurement of organizational performance, both independently and in combination with other multi-criteria or traditional approaches.

The Analytic Hierarchy Process has been applied in a number of studies related to performance

measurement in higher education institutions: V. M. R. Tummala and P. P. Sanchez (1988) successfully applied the AHP in measuring faculty performance; I. C. Ehie and D. Karahtanos, (1994) measured faculty business performance by applying the AHP; in recent years, J. R. Grandzol (2005) has applied the AHP in the process of selecting the optimal faculty to study at; D. N. Ghosh (2011) combined the AHP and the TOPSIS methods in the process of measuring the performance of four engineering faculties etc.

J. Johnes (1996, 2006) gave an overview of the methods that can be used in the measurement and evaluation of the performance of higher education institutions and, through the comparative performance measurement of universities in Great Britain, concluded that the DEA method had the advantage over the other methods. The DEA method was applied in the evaluation of organizational performance in a number of empirical studies relating to the measurement and evaluation of performance in higher education institutions: D. A. Antreas and S. Estelle (1997) used the DEA in the comparative analysis of the efficiency of higher education institutions in Great Britain; C. Ng. Ying and S. K. Li (2000) examined the research performance of higher education institutions in China; M Abbott and C. Doucouliagos (2003), also used the DEA method to evaluate the efficiency of the state universities in Australia; W. H. Kong and T. T. Fu (2012) constructed a student-based performance measurement model of business schools in Taiwan, combining the AHP and the DEA methods; C. Kao and H. T. Hung (2008) used the DEA to assess the effectiveness of the academic departments, as well as J. Nazarko and J. Šaparauskas (2014); Q. H. Do and J-F. Chen (2014) combined the Fuzzy AHP and DEA in measuring the efficiency of universities; B. D. Royendegh and S. Erol (2009) combined the DEA (Data Envelopment Analysis) and the ANP (Analytic Network Process) in measuring university performance etc.

THE METHODOLOGY

R. Ramanathan (2006) proposes a hybrid, DEAHP method, as a way to overcome the shortcomings of the partial application of the DEA and the AHP methods.

The Analytic Hierarchy Process (AHP) (Saaty, 1980) is an intuitive method for formulating and analyzing decisions, based on hierarchical problem structuring and making a pairwise comparison, based on the 1-9 comparison scale (Table 1). As a method that can successfully be used to measure the relative impact of a number of relevant factors on possible outcomes, as well as for prediction, i.e. the distribution of the relative probability of outcomes, it has been used in solving a number of complex decision-making problems. A good overview of the AHP application was given by O. S. Vaidya and S. Kumar (2006), S. Sipahi and M. Timor (2010), A. Ishizaka and A. Labib (2011), N. Subramanian and R. Ramanathan, (2012).

Data Envelopment Analysis (DEA) is a mathematical, non-parametric approach for the calculation of efficiency, based on linear programming, not requiring a specific functional form. It is used to measure the performance of decision-making units (DMU) by reducing multiple inputs to a single „virtual“ input, and multiple outputs to a single „virtual“ output, using weight coefficients, whereby for each organizational unit a corresponding linear programming model is formed and solved. The DEA method has proven

to be successful, especially when evaluating the performance of non-profit organizations operating outside the market, because in their case, the financial performance indicators, such as the revenue and the profit, do not measure efficiency in a satisfactory manner. All data on inputs and outputs for each decision-making unit are entered into a certain linear program, which is actually one of the DEA models. In this way, the performance of the observed decision-making units is evaluated, which represents the ratio of the weighted output sum and the weighted input sum. Data Envelopment Analysis points to a relative efficiency, because decision-making units are observed and measured in relation to the others. Efficiency ranges from 0 to 1, and any deviation from 1 is attributed to an excess of inputs or a lack of outputs.

In the DEAHP problem model, the DEA method is used for deriving local decision-making priorities from the comparison matrix in respect of the observed elements in the AHP model. Tables 2 and 3 show the comparison matrices characteristic of the AHP method and the DEAHP method, respectively. As R. Ramanathan suggests, the elements a_{ij} , $a_{ij} > 0$, $a_{ij} = 1/a_{ji}$, $a_{ii} = 1$ for each i in the AHP comparison matrix

Table 1 The 1-9 comparison scale

Intensity of relative importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one relative to the other	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated importance	One activity is strongly favored, and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Mean values between two close judgments	When compromise is needed.
Reciprocity of the above non-zero numbers		If one activity has one of the above numbers (for example, 3), compared to the other activity, then the second activity has the reciprocal value (i.e. $1/3$), when compared with the other.

Source: Saaty & Kearns, 1985, 27

Table 2 The traditional AHP pairwise comparison matrix

	Element 1	Element 2	...	Element n
Element 1	1	a_{12}	...	a_{1N}
Element 2	$1/a_{12}$	1	...	a_{2N}
...	...	...	...	...
Element N	$1/a_{1N}$	$1/a_{2N}$	...	1

Source: Ramanathan, 2006, 1296

become the elements of the DEAHP comparison matrix in Table 3, adjusted for the application of the DEA method, in order to calculate local priorities. Each row of the matrix is viewed as a typical DMU, and each column as an output. In addition, the matrix contains the column with the so-called dummy, i.e. fictitious input, which takes the value of 1 for each DMU, to implement the DEA method.

R. Ramanathan proves that the application of the DEA method with the AHP comparison matrices provides the objectified values of decision-making priority elements, thus reducing the subjectivity of the assessment with the AHP method, and eliminating the rank inversion, which occurs by either adding or excluding an irrelevant alternative, which is a typical problem with the application of the AHP. The calculated DEA efficiencies can be interpreted as local priorities of decision-making units. Finally, the DEA is used for the aggregation of the finite decision-making priority elements. When the DEA approach is used in this sense, the alternatives are seen as the decision-making units, DMUs, and their local priorities, calculated in relation to each criterion, as the outputs,

Table 3 The DEAHP pairwise comparison matrix and the assessment of their effectiveness

	Output 1	Output 2	...	Output n	Fictitious input
DMU ₁	1	a_2	...	a_{1N}	1
DMU ₂	$1/a_{12}$	1	...	a_{2N}	1
...	...	...	...	...	...
DMU _N	$1/a_{1N}$	$1/a_{2N}$	...	1	1

Source: Ramanathan, 2006, 1296

Table 4 The AHP comparison matrix of the alternatives and the criteria

	Kriterijum 1	Kriterijum 2	...	Kriterijum J
Alternativa 1	y_{11}	y_{12}	...	y_{1J}
Alternativa 2	y_{21}	y_{22}	...	y_{2J}
...	...	...	...	...
Alternativa N	y_{N1}	y_{N2}	...	y_{NJ}

Source: Ramanathan, 2006, 1298

using the dummy inputs column (Tables 4 and 5). On the other hand, unlike the classic DEA approach that only measures relative efficiency, the DEAHP method implicitly including the ability of the AHP to include both quantitative and qualitative decision-making factors results in a more complete performance assessment of the observed decision-making units.

THE DESCRIPTION OF THE PROBLEM AND THE STRUCTURING OF THE DEAHP MODEL FOR THE EVALUATION AND RANKING OF THE FACULTIES IN THE REPUBLIC OF SERBIA

In the present case, the evaluation and ranking of the faculties through the application of the AHP method will be performed by observing 12 faculties within the four state universities (Belgrade, Novi Sad, Nis, and Kragujevac) in the Republic of Serbia, according to five non-financial criteria (Figure 1). The criteria are regarded as the inputs (I_1, I_2, I_3) and the outputs ($O_1,$

Table 5 The DEA approach to evaluating the efficiency of alternatives in relation to the defined criteria

	Kriterijum 1	Kriterijum 2	...	Kriterijum J	Fiktivni ulaz
DMU 1	y_{11}	y_{12}	...	y_{1J}	1
DMU 2	y_{21}	y_{22}	...	y_{2J}	1
...	...	...	...	...	1
DMU N	y_{N1}	y_{N2}	...	y_{NJ}	1

Source: Ramanathan, 2006, 1298

Figure 1 The AHP hierarchical structure of the problem of the evaluation and ranking of the faculties (the criteria are all the identified inputs and outputs).

Source: Authors

O_2), due to the fact that the same will be used in the DEA model. The key inputs are the number of the teachers (I_1), the number of the associates (I_2) at the faculty, and the number of the enrolled students (I_3). The main outputs are the number of the graduates (O_1) and the number of the doctoral dissertations (O_2). The faculties have been chosen from the field of natural, technical, and social sciences and humanities, whereas the criteria (for the application of the AHP method), i.e. the inputs and the outputs (for the application of the DEA method) were selected in accordance with the available data for the 2013/2014 academic year.

Based on the given hierarchical structure, the criterion comparison matrix within the AHP model of the evaluation and ranking of the observed faculties was formed, and together with the comparison based on the 1-9 scale, is shown in Table 6.

Structuring the DEA model for evaluating the efficiency of the faculties in the Republic of Serbia

The number of the DMUs to be compared depends on the objective of the study and the number of the

homogeneous units whose performance in practice should be compared. It is recommended that the number of the DMUs should be larger than the product of the number of the inputs and the outputs, in order to effectively distinguish between an efficient and an inefficient DMU. In the present case, for the purpose of evaluating the efficiency of the faculties in the Republic of Serbia, 12 faculties, i.e. decision-making

Table 6 The criterion comparison matrix within the AHP model of the faculty ranking and evaluation

Criteria	Output 1	Output 2	Input 1	Input 2	Input 3
Output 1	1	2	1/4	1/3	1
Output 2	1/2	1	1/3	1/2	1/4
Input 1	4	3	1	2	2
Input 2	3	2	1	1	1/2
Input 3	1	4	1/2	2	1

Source: Authors

units, were selected, as well as 3 inputs (the number of the teachers, the number of the associates, and the number of the enrolled students) and 2 outputs (the number of the graduates and the number of the doctoral dissertations). The criteria for the selection of these inputs and outputs are quite subjective. There is no specific rule in determining the procedures for the selection of inputs and outputs. A set of inputs and outputs for measuring performance in the education sector is often criticized for its being inadequate and unsuitable for an efficiency analysis. Thus, the set is subject to change in accordance with research requirements. One of the reasons for this selection of the inputs and the outputs lies in a lack of up-to-date data and a lack of access to certain data on the inputs and the outputs in respect of the observed faculties.

Table 7 provides an overview of the structured DEA model for evaluating the efficiency of the faculties in the Republic of Serbia.

When applying a data envelopment analysis, the output-oriented CRS DEA model, which seeks to maximize the output at the given input level, where

Table 7 Structuring DEA model for evaluating the efficiency of the faculties

Faculty	Input 1	Input 3	Input 2	Output 1	Output 2
F ₁	52	510	32	424	34
F ₂	100	1350	36	1060	71
F ₃	64	305	49	287	45
F ₄	71	543	12	210	32
F ₅	43	739	18	321	18
F ₆	35	445	24	172	24
F ₇	79	306	40	176	88
F ₈	40	306	25	374	24
F ₉	57	272	41	98	42
F ₁₀	26	204	20	140	6
F ₁₁	35	94	11	35	5
F ₁₂	98	591	71	600	81

Source: Information brochures on the work of the faculty for the academic year 2013/2014.

an inefficient unit becomes an efficient one through an increase in its outputs, was used.

The mathematical form of this model is as follows:

$$\begin{aligned} \max h_k &= \sum_{r=1}^s u_r \times y_{ro} \\ \sum_{r=1}^s u_r \times y_{rj} - \sum_{i=1}^m v_i \times x_{ij} &\leq 0, j = 1, \dots, n \\ \sum_{i=1}^m v_i \times x_{io} &= 1 \\ u_r &\geq 0, v_i \geq 0 \end{aligned}$$

where:

y_{rj} - the output value,

x_{ij} - the input value,

u_r - the weight coefficient of the output y_{rj} ,

v_j - the weight coefficient of the input x_{ij} ,

$r = 1, 2, \dots, s$ - the number of the recorded products,

$i = 1, 2, \dots, m$ - the number of the used resources,

$j = 1, 2, \dots, n$ - the number of the DMUs.

Namely, in the observed problem for the faculty F1, the corresponding CRS DEA linear model is as follows:

$$\max h_k = 424 y_1 + 34 y_2$$

With the system of limitations:

$$52 x_1 + 32 x_2 + 510 x_3 = 1$$

$$424 y_1 + 34 y_2 - (52 x_1 + 32 x_2 + 510 x_3) \leq 0$$

$$1060 y_1 + 71 y_2 - (100 x_1 + 36 x_2 + 1350 x_3) \leq 0$$

$$287 y_1 + 45 y_2 - (64 x_1 + 49 x_2 + 305 x_3) \leq 0$$

$$210 y_1 + 32 y_2 - (71 x_1 + 12 x_2 + 543 x_3) \leq 0$$

$$321 y_1 + 18 y_2 - (43 x_1 + 18 x_2 + 739 x_3) \leq 0$$

$$172 y_1 + 24 y_2 - (35 x_1 + 24 x_2 + 445 x_3) \leq 0$$

$$176 y_1 + 88 y_2 - (79 x_1 + 40 x_2 + 306 x_3) \leq 0$$

$$374 y_1 + 24 y_2 - (40 x_1 + 25 x_2 + 306 x_3) \leq 0$$

$$98 y_1 + 42 y_2 - (57 x_1 + 41 x_2 + 272 x_3) \leq 0$$

$$140 y_1 + 6 y_2 - (26 x_1 + 20 x_2 + 204 x_3) \leq 0$$

$$35 y_1 + 5 y_2 - (35 x_1 + 11 x_2 + 94 x_3) \leq 0$$

$$600 y_1 + 81 y_2 - (98 x_1 + 71 x_2 + 591 x_3) \leq 0$$

$$y_1, y_2 \geq 0$$

$$x_1, x_2, x_3 \geq 0$$

Appropriate models are formed in the same way as for other decision-making units, i.e. the faculties.

THE RESULTS OF THE APPLICATION OF THE AHP, DEA, AND DEAHP METHODS

The results of the AHP method

The Superdecision software package was used to calculate the weight coefficients of the criteria, and, on the basis of them, the final alternative priorities. Table 8 shows that the highest priority and rank 1 is given to the criterion Number of teachers (0.368173), and the lowest rank to the criterion Number of doctoral dissertations (0.078690).

The final ranking of the alternatives within the AHP model for the evaluation and ranking of the faculties by using the Superdecision software package is accounted for in Table 9. The results obtained show that Faculty 12 is ranked the best, only to be followed by Faculty 2, ranked the second.

Table 8 The weight coefficients and the rank within the AHP model for the evaluation and ranking of the faculties, calculated by using the Superdecision software package

Criterion	Weight coefficients	Rank
Output 1	0.126346	4
Output 2	0.078690	5
Input 1	0.368173	1
Input 2	0.193262	3
Input 3	0.233529	2

Consistency ratio: CR = 0,0742

Source: Authors

Table 9 The priorities and the final ranking of the alternatives within the AHP model for the evaluation and ranking of the faculties

Alternative	Total	Normalized	Idealized	Rank
Faculty 1	0.0394	0.0788	0.3519	5
Faculty 2	0.1107	0.2214	0.9886	2
Faculty 3	0.0414	0.0829	0.3699	4
Faculty 4	0.0360	0.0721	0.3219	6
Faculty 5	0.0352	0.0704	0.3144	7
Faculty 6	0.0185	0.0370	0.1654	9
Faculty 7	0.0445	0.0890	0.3972	3
Faculty 8	0.0170	0.0340	0.1518	10
Faculty 9	0.0295	0.0590	0.2633	8
Faculty 10	0.0087	0.0174	0.0775	11
Faculty 11	0.0070	0.0140	0.0626	12
Faculty 12	0.1120	0.2240	1.0000	1

Source: Authors

In the event that the process of evaluation and comparison involves several experts, i.e. decision-makers, it is possible to use the geometric mean as a way to combine and objectify the assessment (Saaty & Peniwati, 2008):

$$w_i = \sqrt[k]{\prod_{k=1}^K w_{ik}} \quad \forall i$$

where w_i is the final weight of the i -th factor, and the relative weight of the i -th element, calculated on the basis of the assessment of the k -th evaluator.

The results of the DEA method

For the evaluation of the efficiency of the faculties in the Republic of Serbia, the input-oriented CCR model was used, with a constant return to scale (CRS). The results presented in Table 10 were obtained from the three inputs (the number of the teachers, the number of the associates, the number of the enrolled students) and the two outputs (the number of the graduates, the number of the doctoral dissertations). Given the fact that the literature abounds in dilemmas about the relationship between the DMU and the number

Table 10 The efficiency and optimal values of the weight coefficients of the inputs and the outputs within the output-oriented CRS DEA model

DMU No.	DMU Name	Efficiency	Input 1	Input 2	Input 3	Output 1	Output 2
1	F1	0.90949	0.01453	0.00000	0.00048	0.00115	0.01241
2	F2	1.00000	0.00000	0.00725	0.00055	0.00069	0.00383
3	F3	0.95397	0.00000	0.00000	0.00328	0.00224	0.00692
4	F4	1.00000	0.00000	0.05362	0.00066	0.00101	0.02464
5	F5	0.70426	0.02326	0.00000	0.00000	0.00219	0.00000
6	F6	0.75553	0.02857	0.00000	0.00000	0.00113	0.02339
7	F7	1.00000	0.00000	0.00000	0.00327	0.00000	0.01136
8	F8	1.00000	0.00000	0.00000	0.00327	0.00223	0.00690
9	F9	0.67119	0.01754	0.00000	0.00000	0.00069	0.01436
10	F10	0.57332	0.03160	0.00000	0.00088	0.00410	0.00000
11	F11	0.36652	0.00000	0.00000	0.01064	0.00726	0.02247
12	F12	0.99293	0.00851	0.00000	0.00028	0.00067	0.00727

Source: Authors

of input and output values, it is proposed that the number of DMUs is at least two times larger than the sum of input and output values ($2 + 1$). Bearing in mind the fact that the proposed model has a total of five variables (3 inputs and 2 outputs), the minimum number of decision-making units is 10. In this model, 12 DMUs, i.e. 12 faculties in the Republic of Serbia, were used. The efficiency was determined by using the DEA Frontier software package.

The results demonstrated in Table 11 point to the conclusion that the faculties F2, F4, F7, and F8 are relatively efficient, i.e. the 4 decision-making units form an efficient envelope. Their efficiency is 1, which means that they do not have „surpluses” in the input or „deficits” in the output variables. The other faculties may be regarded as relatively inefficient.

The results of the DEAHP method

In accordance with R. Ramanathan's suggestions (2005), the DEA method can be used for deriving the objectified local decision-making priority elements. As B. R. Royendegh and S. Erol (2009) have also shown, it is possible to establish and implement an

effective model for ranking decision-making units with multiple outputs and inputs, using the DEA method combined with the AHP/ANP methods. Table

Table 11 The efficiency and ranking of the faculties, calculated by using the output-oriented CRS DEA model

Faculty	Efficiency	Rank
F1	0.90949	7
F2	1.00000	1
F3	0.95397	6
F4	1.00000	1
F5	0.70426	9
F6	0.75553	8
F7	1.00000	1
F8	1.00000	1
F9	0.67119	10
F10	0.57332	11
F11	0.36652	12
F12	0.99293	5

Source: Authors

12 shows the criterion comparison matrix, where the evaluation input values result from the AHP criterion comparison based on the 1-9 scale. These values can be further used, as suggested by Ramanathan, as the output values in the corresponding DEA model (Table 13), which the column of the fictitious input values is also added to, as a condition for the establishment and application of the DEA model. The application of the DEA method in such a structured problem results in the relative efficiency of inputs and outputs, i.e. the selected criteria, which, however, are not of importance for the further implementation of the DEAHP method, given the fact it is not necessary that either they or their relative importance should be taken into account when forming the DEAHP comparison matrix and calculating the DEAHP relative efficiency of alternatives. Table 14 shows the DEAHP criterion comparison matrix, while Table 15 presents the comparison matrix of the decision-making units, the alternatives, in relation to Output 1. The input values are evaluations resulting from comparing pairs of alternatives, the faculties, in the AHP model. The table usually includes a column with the fictitious input value, as well as output columns, in order to apply the DEAHP model. Table 16 presents the calculated DEAHP relative efficiencies of the decision-making units, i.e. their local priorities, in relation to Output 1.

The relative efficiencies of the alternatives, the faculties, observed in relation to Output 1, are shown in Table 16. The alternative comparison matrices in relation to Output 2, as well as the other inputs, can be formed in the same manner, followed by the application of

Table 12 The criterion comparison matrix within the AHP model for the evaluation and ranking of the faculties

Criteria	Output 1	Output 2	Input 1	Input 2	Input 3
Output 1	1	2	1/4	1/3	1
Output 2	1/2	1	1/3	1/2	1/4
Input 1	4	3	1	2	2
Input 2	3	2	1	1	1/2
Input 3	1	4	1/2	2	1

Source: Authors

Table 13 The DEAHP comparison matrix for the evaluation of the efficiency of the criteria

DMU	I1	O1	O2	O3	O4	O5
I1	1	1	2	0.250	0.333	1
I2	1	0.5	1	0.333	0.5	0.25
O1	1	4	3	1	2	2
O2	1	3	2	1	1	0.5
O3	1	1	4	0.5	2	1

Source: Authors

Table 14 The efficiency of the criteria calculated by using the DEAHP method

DMU No.	DMU name	Efikasnost
1	I1	0.60000
2	I2	0.70000
3	O1	1.00000
4	O2	1.00000
5	O3	1.00000

Source: Authors

the DEA method to determine local priorities, i.e. the relative efficiencies of the decision-making units observed.

Since the local alternative priorities are calculated in relation to all individual inputs and outputs, the next step is the formation of the DEAHP alternative comparison matrix (Table 17) in relation to all the criteria simultaneously, whereby the input values of the matrix are represented by the local alternative priorities, calculated in relation to individual criteria, where the table usually includes the column of the fictitious input value to implement the DEA method. The final priorities of the alternatives, i.e. their DEAHP relative efficiencies, are given in Table 18, from which it is clear that the faculties F1, F2, F3, F5, F7, F9, and F12 are relatively efficient, while the others are relatively inefficient, with the faculty F11 being ranked the lowest. Finally, Table 19 presents a comparative overview of the alternative priorities, i.e. their relative efficiencies¹, calculated by using all the three methods.

Table 15 The DEAHP alternative comparison matrix in relation to Output 1

DMU	I1	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12
F1	1	1	0.5	4.000	5	3	5	5	3	7	5	7	0.333
F2	1	2	1	6	7	5	8	8	5	8	7	9	4
F3	1	0.2	0.167	1	3	0.5	4	4	0.25	4	3	6	0.2
F4	1	0.2	0.143	0.333	1	0.333	4	4	0.333	4	3	5	0.2
F5	1	0.333	0.2	2	3	1	3	3	0.333	5	4	7	0.2
F6	1	0.2	0.125	0.25	0.25	0.333	1	0.5	0.2	3	2	4	0.143
F7	1	0.2	0.125	0.25	0.25	0.333	2	1	0.25	4	3	6	0.143
F8	1	0.333	0.2	4	3	3	5	4	1	7	6	8	0.25
F9	1	0.143	0.125	0.25	0.25	0.2	0.333	0.25	0.143	1	0.5	4	0.125
F10	1	0.2	0.143	0.333	0.333	0.25	0.5	0.333	0.167	2	1	4	0.125
F11	1	0.143	0.111	0.167	0.2	0.143	0.25	0.167	0.125	0.25	0.25	1	0.111
F12	1	3	0.25	5	5	5	7	7	4	8	8	9	1

Consistency ratio: CR = 0,09886

Source: Authors

Table 16 DEAHP relative efficiency of alternatives in relation to Output 1

DMU No.	DMU name	Efficiency
1	F1	0.87500
2	F2	1.00000
3	F3	0.66667
4	F4	0.55556
5	F5	0.77778
6	F6	0.44444
7	F7	0.66667
8	F8	0.88889
9	F9	0.44444
10	F10	0.44444
11	F11	0.11111
12	F12	1.00000

Source: Authors

Table 17 The local alternative priorities in relation to the criteria (outputs and inputs)

DMU	I1	C1	C2	C3	C4	C5
F1	1	0.55556	0.66667	0.833	0.875	1
F2	1	1	0.66667	1	1	1
F3	1	0.77778	1	0.44444	0.66667	0.66667
F4	1	0.77778	0.11111	0.88889	0.55556	0.5
F5	1	0.44444	0.33333	1	0.77778	0.22979
F6	1	0.33333	0.44444	0.75	0.44444	0.26047
F7	1	0.875	0.66667	0.5	0.66667	1
F8	1	0.44444	0.44444	0.11111	0.88889	0.33617
F9	1	0.57143	0.66667	0.55556	0.44444	1
F10	1	0.11111	0.33333	0.44444	0.44444	0.12077
F11	1	0.22222	0.11111	0.25	0.11111	0.12077
F12	1	1	1	0.88889	1	1

Source: Authors

Table 18 The final priorities of the alternatives calculated by applying the DEAHP method

DMU No.	DMU name	Efficiency
1	F1	1.00000
2	F2	1.00000
3	F3	1.00000
4	F4	0.88889
5	F5	1.00000
6	F6	0.75000
7	F7	1.00000
8	F8	0.88889
9	F9	1.00000
10	F10	0.45454
11	F11	0.25000
12	F12	1.00000

Source: Authors

Table 19 The comparative analysis of the priorities of the alternatives, obtained by using the AHP, the DEA, and the DEAHP methods

	AHP efficiencies	DEA priorities (efficiencies)	DEAHP priorities
F ₁	0.3519	0.90949	1.00000
F ₂	0.9886	1.00000	1.00000
F ₃	0.3699	0.95397	1.00000
F ₄	0.3219	1.00000	0.88889
F ₅	0.3144	0.70426	1.00000
F ₆	0.1654	0.75553	0.75000
F ₇	0.3972	1.00000	1.00000
F ₈	0.1518	1.00000	0.88889
F ₉	0.2633	0.67119	1.00000
F ₁₀	0.0775	0.57332	0.45454
F ₁₁	0.0626	0.36652	0.25000
F ₁₂	1.0000	0.99293	1.00000

Source: Authors

It is noticeable that the faculties F2 and F12 have the matching priority values, calculated by using all the three methods, which only confirms the fact that these are the best performing faculties.

CONCLUSION

This paper has presented a hybrid DEAHP method for measuring and evaluating the performance of the 12 state faculties in the Republic of Serbia. The idea was to take on a new, comprehensive approach and, through the integrated and combined use of the DEA and the AHP methods, obtain a more complete and objective evaluation of faculty performance and perform their ranking. The ultimate goal of this study was to improve the evaluation process of higher education institutions in Serbia, using the multi-criteria analysis methods.

The proposed approach of combining the Analytic Hierarchy Process, as a method for decision-making support in terms of complexity and uncertainty, and robust non-parametric methods, such as the Data Envelopment Analysis, provides a flexible, systematic, and objective framework for a comprehensive (absolute and relative) efficiency measurement and performance evaluation, and, implicitly, stands for a reliable basis for making high-quality strategic decisions in higher education institutions. Through the simultaneous use of the non-financial indicators and the possibility of including not only the quantitative but also the qualitative factors and their combination (through the AHP), the proposed approach significantly reduces the subjectivity and bias frequently present in the measurement and evaluation of organizational performance. In theoretical and methodological terms, some dilemmas remain, relating to the functioning of the DEAHP method in the case of inconsistent evaluation matrices (Ramanathan, 2006), which can, however, be verified or denied in future empirical research. It would be useful to perform a solution sensitivity analysis and check whether and how changes in the relative importance of the selected criteria in the AHP method affect the ranking of the alternatives, and what consequences this may have for

the integrated application with the DEA method, both generally and in specific cases.

Based on the results obtained, it can be concluded that there are potentially wide possibilities of the application of the scientifically based multi-criteria analysis methods and models, especially in the field of higher education, which creates better conditions for making high-quality management decisions with long-term effects on society. If viewed in a broader social context, the results of the conducted research can contribute to the improvement of the management and governance systems within higher education institutions, and can be a significant indicator of the further development of higher education institutions and the Serbian society as a whole. Furthermore, the results can form the basis for future studies, in combination and by comparison with the results obtained by other multi-criteria decision-making methods in order to find the best combination of methods for the evaluation and ranking of not only higher education institutions in the context of the continuous higher education reform process, but also of other non-profit organizations in the Republic of Serbia.

In fact, the conducted process of efficiency evaluation and performance measurement of the observed faculties has had certain limitations, the most important ones being related to the fact that the analysis included a relatively small number of the model inputs and outputs, and omitted those relating to scientific research and the financial component, as extremely important dimensions for the functioning of the observed higher education institutions. By including these factors into the analysis, a more realistic, multidimensional evaluation of faculty performance would be obtained, which makes room for a new interpretation of the results obtained, a correlation analysis, a solution sensitivity analysis, and further research in this direction. In addition, due to a lack of up-to-date and transparent data, and despite the obligation of publishing annual information brochures on the work of the faculties, there is no possibility of forming sufficiently long data time series that would enable various econometric analyses and a comparison of actual faculty performance by periods.

ENDNOTE

- 1 It is known that the priorities of the AHP model can be interpreted in various ways, depending on the context of the problem. In this case, they have the meaning of efficiency. The efficiencies of the alternatives, calculated by using the AHP method, are taken from the column of the idealized values, obtained by dividing all the individual priority values by the highest value in the column of the normalized values.

REFERENCES

- Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: A data envelopment analysis. *Economics of Education Review*, 22(1), 89-97, doi: 10.1016/S0272-7757(01)00068-1.
- Antreas, D. A., & Estelle, S. (1997). Assessing the comparative efficiency of Higher education institutions in the UK by means of data envelopment analysis. *Education Economics*, 5(2), 117-134, doi: 10.1080/09645299700000011.
- Aruldoss, M., Lakshmi, T. M., & Venkatesan, V. P. (2013). A survey on multicriteria decision making methods and its applications. *American Journal of Information Systems*, 1(1), 31-43, doi: 10.12691/ajis-1-1-5.
- Do, Q. H., & Chen, J-F. (2014). A hybrid fuzzy AHP-DEA approach for assessing university performance. *WSEAS Transactions on Business and Economics*, 11, 386-397.
- Ehie, I. C., & Karathanos, D. (1994). Business faculty performance evaluation based on the new AACSB accreditation standards. *Journal of Education for Business* 69(5), 257-262, doi: 10.1080/08832323.1994.10117695.
- Ghosh, D. N. (2011). Analytic hierarchy process & TOPSIS method to evaluate faculty performance in engineering education. *Dipendra Nath Ghosh et al UNIASCIT*, 1(2), 63-70.
- Grandzol, J. R. (2005). Improving the faculty selection process in higher education: A case for the analytic hierarchy process. *IR Applications* 6, Bloomsburg University of Pennsylvania, 1-13, ERIC Number: ED504373.
- Ishizaka, A., & Labib, A. (2011). Review of the main developments in the analytic hierarchy process. *Expert Systems with Applications*, 38(11): 14336-14345, doi: 10.1016/j.eswa.2011.04.143
- Johnes, J. (1996). Performance assessment in higher education in Britain. *European Journal of Operational Research*, 89(1), 18-33, doi: 10.1016/S0377-2217(96)90048-X

- Johnes, J. (2006). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, 25(3), 273-288, doi: 10.1016/j.econedurev.2005.02.005
- Kao, C., & Hung, H. T. (2008). Efficiency analysis of university departments: An empirical study. *Omega*, 36(4), 653-664, doi: 10.1016/j.omega.2006.02.003
- Kong, W. H., & Fu, T. T. (2012). Assessing the performance of business colleges in Taiwan using data envelopment analysis and student based value-added performance indicators. *Omega*, 40(5), 541-549, doi: 10.1016/j.omega.2011.10.004
- Nazarko, J., & Šaparauskas, J. (2014). Application of DEA method in efficiency evaluation of public higher education institutions. *Tehnological and Economic Development of Economy*, 20(1), 25-44, doi: 10.3846/20294913.2014.837116.
- Ramanathan, R. (2006). Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. *Computers & Operations Research*, 33, 1289-1307, doi: 10.1016/j.cor.2004.09.020
- Royendegh, B. D., & Erol, S. (2009). A DEA-ANP hybrid algorithm approach to evaluate a university's performance. *International Journal of Basic & Applied Sciences*, 9(10), 115-129.
- Saaty, T. L. (1980). *The Analytic Hierarchy Process*. New York, NY: McGraw-Hill.
- Saaty, T., & Kearns, K. (1985). *Analytical Planning: The Organization of Systems*. Pittsburgh: Pergamon Press.
- Saaty, T., & Peniwati K. (2008). *Group decisionmaking: drawing out and reconciling differences*. 1, RWS, Pittsburgh.
- Saad, G. (2001). Strategic performance evaluation: descriptive and prescriptive analysis. *Industrial management and Data system*, 101(8), 390-399, <http://dx.doi.org/10.1108/EUM000000000006169>
- Sipahi, S., & Timor, M. (2010). The Analytic hierarchy process and Analytic Network Process: an overview of applications. *Management decision*, 48(5), 775-808, <http://dx.doi.org/10.1108/00251741011043920>
- Subramanian, N., & Ramanathan, R. (2012). A review of applications of Analytic Hierarchy Process in operations management. *Int. J. Production Economics*, 138, 215-241, doi:10.1016/j.ijpe.2012.03.036
- Tangen, S. (2005). Analysing the requirements of performance measurement systems. *Measuring Business Excellence* 9(4), 46-54, <http://dx.doi.org/10.1108/13683040510634835>
- Tummala, V. M. R., & Sanchez, P. P. (1988). Evaluating faculty merit awards by analytic hierarchy process. *Modeling, Simulation and Control C: Environmental, Biomedical, Human and Social Systems* 11(4), 1-13.
- Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal Of Operational Research*, 169(1), 1-29, doi:10.1016/j.ejor.2004.04.028
- Ying, C. Ng., & Li, S. K. (2000). Measuring the research performance of Chinese Higher education institutions: an application of Data envelopment analysis. *Education Economics*, 8(2), 139-156, doi: 10.1080/096452900410712.
- <http://www.superdecisions.com/~saaty/.../SuperDecisionsManualMar2005.doc/>

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Pregledni članak

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INTEGRISANA PRIMENA METODA ANALITIČKOG HIJERARHIJSKOG PROCESA I ANALIZE OBAVIJANJA PODATAKA U VREDNOVANJU PERFORMANSI VISOKOG OBRAZOVANJA U REPUBLICI SRBIJI

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Merenje i ocena uspešnosti u ostvarivanju rezultata, od ključnog su značaja za efektivno i efikasno funkcionisanje ekonomskih sistema, jer se na taj način prati u kojoj meri se ostvaruju definisani ciljevi. Organizacione performanse se mere različitim metodama, kvantitativnim i kvalitativnim. Mnogi od poznatih metoda za ocenu i merenje organizacionih performansi uzimaju u obzir samo finansijske, a zanemaruju nefinansijske pokazatelje. Integralno obuhvatanje jednih i drugih pokazatelja, kombinovanom primenom više metoda, kao i poređenje njihovih rezultata, treba da omogući potpuniju i objektivniju meru organizacione performanse. Analitički hijerarhijski proces (AHP) predstavlja formalan okvir za rešavanje kompleksnih problema višekriterijumskog odlučivanja, kao i sistemsku proceduru za hijerarhijsko prikazivanje elemenata nekog problema. Analiza obavljanja podataka (DEA) predstavlja neparametarski pristup baziran na linearnom programiranju, koji omogućuje izračunavanje efikasnosti jedinica odlučivanja u okviru grupe organizacija. Rad je ilustracija načina i okvira kombinovanog korišćenja metoda višekriterijumske analize, u vrednovanju performansi visokog obrazovanja u Republici Srbiji. Prednosti ovakvog pristupa ogledaju se u prevazilaženju nedostataka parcijalne primene AHP i DEA metoda korišćenjem novog, hibridnog DEAHP (Data Envelopment Analytic Hierarchy Process) metoda. Vrednovanje performansi, integrisanom primenom AHP i DEA metoda, daje objektivnije rezultate i pouzdanija rešenja posmatranog problema i na taj način stvara vrednu informacionu osnovu za donošenje kvalitetnih strategijskih odluka u visokom obrazovanju, na nacionalnom nivou i nivou pojedinačnih institucija.

Cljučne reči: višekriterijumska analiza, analitički hijerarhijski proces, analiza obavljanja podataka, organizacione performanse, visoko obrazovanje

JEL Classification: C44, C61, D81, I23

UVOD

Ocena organizacionih performansi je jedna od najvažnijih aktivnosti za sve menadžere i

stejkholdere. Kao alat koji im omogućuje da procene organizacione snage i slabosti, kao i kompetitivne prednosti u odnosu na konkurenciju, ocena organizacionih performansi stvara pretpostavke za definisanje smernica i izbor mera koje moraju biti preduzete u cilju prevazilaženja postojećih problema.

Organizacione performanse, generalno, su, po pravilu,

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višedimenzionalne i pod uticajem brojnih faktora, kao što su: finansijski faktori, kao indikator finansijske pozicije organizacije; strategijski faktori kvalitativne prirode, koji determinišu interne aktivnosti organizacije i njihovu povezanost s tržištem; ekonomski faktori koji uključuju poslovno okruženje, itd. Agregacija svih ovih faktora u kompozitnu, ukupnu meru performanse, je subjektivan i kompleksan proces koji zavisi od sistema vrednosti i sistema preferencija donosioca odluka u procesu odlučivanja. Izrada sistema za merenje performansi je, zbog toga, kompleksan zadatak; šta je to što se može smatrati optimalnim sistemom za merenje performansi, razlikovaće se od slučaja do slučaja (Tangen, 2005). Pri tome, važno je razumeti kako bi sistemi merenja učinka trebalo da se razvijaju i da se integrišu u modelima upravljanja organizacija. Ovakvi stavovi su konzistentni s bazičnom paradigmom višekriterijumskog procesa odlučivanja, što je kao posledicu imalo brojna istraživanja mogućnosti primene višekriterijumskog odlučivanja u procesu merenja i ocene organizacionih performansi (Aruldoss, Lakshmi & Venkatesan, 2013).

Kao posledica Bolonjskog procesa, internacionalizacije i uvođenja privatnih koledža i univerziteta, visokoobrazovne institucije su izložene sve većoj konkurenciji. Javlja se stalna potreba za poređenjem različitih obrazovnih institucija, kako bi oni koji žele da upišu fakultete mogli da se odluče za najbolji prema nekom od kriterijuma koje sagledavaju. Cilj rangiranja je da se uspostavi transparentnost i da na taj način informacije o univerzitetima budu korisne za više ciljnih grupa, kao što su đaci koji završavaju srednju školu, njihovi roditelji, univerzitetski profesori, univerzitetski menadžeri, ministarstva i poslodavci. Brojne studije pokazuju da rangovi univerziteta utiču na izbor fakulteta/univerziteta kod đaka koji završavaju školu. G. Saad (2001) navodi da analiza performansi omogućuje efektivnu i efikasnu alokaciju raspoloživih resursa. Ona, takođe, omogućuje planerima u visokom obrazovanju da identifikuju univerzitete s najvišim nivoom performansi.

Predmet istraživanja je merenje performansi visokoškolskih institucija u Republici Srbiji (RS). Iako je najavljivano, vrednovanje i rangiranje univerziteta i fakulteta u RS, formalno nije izvršeno, niti su precizirani kriterijumi i način na koji će se rangiranje

realizovati. U tom smislu, na primeru dvanaest fakulteta, sa četiri državna univerziteta u RS (Beograd, Novi Sad, Niš i Kragujevac), za akademsku 2013/2014 godinu, u radu je predlažen novi pristup, koji eliminiše proizvoljnost i pristrasnost za njihovu ocenu i rangiranje.

Cilj rada je da se integrisanom primenom određenih metoda višekriterijumskog odlučivanja unapredi proces vrednovanja performansi u visokom obrazovanju RS.

U skladu sa određenim predmetom i ciljem istraživanja, formulisana je sledeća hipoteza:

H: Primena hibridnog DEAHP (*Data Envelopment Analytic Hierachy Process*) metoda, kroz sinergijski efekat kombinovane primene AHP (*Analytic Hierarchy Process*) i DEA (*Data Envelopment Analysis*) metoda, definiše formalni, naučno utemeljen okvir za merenje i ocenu performansi u visokom obrazovanju, čime se stvaraju pretpostavke za njihovo objektivno i efikasno rangiranje.

Rad je strukturiran na sledeći način: najpre je dat kratak teorijski osvrt na problematiku i najznačajnije aspekte merenja organizacionih performansi. Zatim su, u pregledu literature, navedene najznačajnije reference koje tangiraju primenu AHP i DEA metoda u visokom obrazovanju, nakon čega su ukratko objašnjeni metodi korišćenii u radu - AHP, DEA i DEAHP. U poslednjem delu rada je na primeru merenja efikasnosti i rangiranja dvanaest izabranih fakulteta u RS, pokazano kako se kombinovanim korišćenjem ovih metoda dobija sveobuhvatna i objektivizirana ocena performansi posmatranih fakulteta.

PREGLED LITERATURE

Višekriterijumska analiza se u praksi pokazala kao pogodan teorijsko-metodološki instrumentarijum za obuhvatanje i rešavanje brojnih problema odlučivanja, u kompanijama i u neprofitnim organizacijama. Raznovrsna priroda faktora koji utiču na proces odlučivanja, kompleksnost ekonomskog okruženja, subjektivna priroda mnogih odluka, su neke od

karakteristika finansijskih odluka, koje omogućuju primenu višekriterijumskog metodološkog okvira. Potreba istovremenog posmatranja više kriterijuma, koji uključuju lične preferencije donosioca odluka, važna je komponenta funkcije menadžmenta. Primena višekriterijumskog odlučivanja dopušta donosiocu odluka (menadžeru) da aktivno učestvuje u procesu donošenja odluka i pomaže mu u razumevanju i suočavanju s kompleksnošću i neizvesnošću kao karakteristikama poslovnog okruženja. To znači da njegova uloga nije svedena na pasivnu implementaciju optimalnog rešenja (ukoliko ono postoji) dobijenog iz primenjenog višekriterijumskog modela, već on aktivno učestvuje u procesu strukturiranja i modeliranja problema, kao i u analizi, interpretaciji i implementaciji dobijenih rezultata. Može se reći da višekriterijumsko odlučivanje obezbeđuje široku lepezu tehnika za sintezu više kriterijuma u problemima merenja performansi u cilju izbora, rangiranja, klasifikacije i opisivanja skupa alternativnih opcija, o čemu govore i brojne naučne i stručne reference.

Tehnike višekriterijumskog odlučivanja, kao što su Analitički hijerarhijski proces, Analitički mrežni proces, i druge, ekstenzivno su korišćene u merenju organizacionih performansi, kako samostalno, tako i u kombinaciji s drugim višekriterijumskim ili tradicionalnim pristupima.

Analitički hijerarhijski proces je primenjivan u brojnim istraživanjima koja se odnose na merenje performansi u visokom obrazovanju: V. M. R. Tummala i P. P. Sanchez (1988) uspešno primenjuju AHP u merenju performansi fakulteta; I. C. Ehie i D. Karahtanos (1994) mere poslovne performanse fakulteta primenom AHP; novije vreme J. R. Grandzol, (2005) primenjuje AHP u procesu izbora optimalnog fakulteta za studiranje; D. N. Ghosh (2011) kombinuje AHP i TOPSIS metodu u procesu merenja performansi četiri fakulteta za inženjersko obrazovanje, itd.

J. Johnes (1996; 2006) daje pregled metoda koji mogu biti korišćeni u merenju i oceni performansi u visokom obrazovanju, i, na primeru komparativnog merenja efikasnosti univerziteta u Velikoj Britaniji, zaključuje da DEA metod ima prednost u odnosu na druge metode. DEA metod je primenjivan u oceni organizacione efikasnosti u brojnim empirijskim istraživanjima koji

se odnose na merenje i ocenu performansi u visokom obrazovanju: D. A. Antreas i S. Estelle (1997) koriste DEA u komparativnoj analizi efikasnosti visokog obrazovanja u Velikoj Britaniji; C. Ng. Ying i S. K. Li (2000) ispituju istraživačke performanse visokoškolskih institucija u Kini; M. Abbott i C. Doucouliagos (2003), takođe, koriste DEA metod u oceni efikasnosti državnih univerziteta u Australiji; W. H. Kong i T. T. Fu (2012) su konstruisali na studentima zasnovan model merenja performansi poslovnih škola na Tajvanu, koji kombinuje AHP i DEA metod; C. Kao i H. T. Hung (2008) koriste DEA u oceni efikasnosti akademskih departmana, kao i J. Nazarko i J. Šaparauskas (2014); Q. H. Do i J-F. Chen (2014) kombinuju fazi AHP i DEA za merenje efikasnosti univerziteta; B. D. Royendegh i S. Erol (2009) kombinuju DEA i ANP (Analytic Network Process) u merenju univerzitetskih performansi, itd.

METODOLOGIJA

R. Ramanathan (2006), predlaže hibridni, DEAHP metod, kao način za prevazilaženje nedostataka parcijalne primene DEA i AHP metoda. Analitički hijerarhijski proces (Saaty, 1980) je intuitivni metod za formulisanje i analiziranje odluka, baziran na hijerarhijskom strukturiranju problema i poređenjima elemenata odlučivanja po parovima, prema skali poređenja 1-9 (Tabela 1). Kao metod koji se uspešno može upotrebiti za merenje relativnog uticaja brojnih, relevantnih faktora na moguće ishode, kao i za predviđanje, tj. izvođenje distribucije relativnih verovatnoća ishoda, korišćen je u rešavanju mnogih kompleksnih problema odlučivanja. Pregled AHP aplikacija dali su O. S. Vaidya i S. Kumar (2006), S. Sipahi i M. Timor (2010), A. Ishizaka i A. Labib (2011) i N. Subramanian i R. Ramanathan, (2012).

Analiza obavljanja podataka (DEA) je matematički, neparametarski pristup za izračunavanje efikasnosti, koji se zasniva na linearnom programiranju i koji ne zahteva specifičnu funkcionalnu formu. Koristi se za merenje performansi jedinica odlučivanja (Decision Making Unit - DMU), tako što se više ulaza svodi na jedan „virtuelni“ ulaz, i više izlaza svodi na jedan „virtuelni“ izlaz, pomoću težinskih koeficijenata, pri čemu se za svaku organizacionu jedinicu formira i

rešava odgovarajući model linearnog programiranja. DEA metod se pokazao uspešnim, posebno prilikom procene efikasnosti neprofitnih organizacija koje posluju van tržišta, jer u njihovom slučaju finansijski indikatori performansi, kao što su prihod i profit, ne mere efikasnost na zadovoljavajući način. Svi podaci o ulazima i izlazima za svaku jedinicu odlučivanja, ubacuju se u određeni linearni program koji je, zapravo, neki od DEA modela. Tako se ocenjuje efikasnost posmatranih jedinica odlučivanja, koja, u stvari, predstavlja odnos težinske sume izlaza i težinske sume ulaza. Kod analize obavljanja podataka radi se o relativnoj efikasnosti jer se jedinice odlučivanja posmatraju i mere u odnosu na ostale. Efikasnost se kreće od 0 do 1, a svako odstupanje od 1 se pripisuje višku ulaza ili manjku izlaza.

U DEAHP modelu nekog problema, DEA metod se koristi za deriviranje lokalnih prioriteta elemenata odlučivanja iz matrice poređenja posmatranih elemenata u AHP modelu. U Tabelama 2 i 3, prikazane su matrice poređenja karakteristične za AHP metod i za DEAHP metod, respektivno. Kao što R. Ramanathan sugeriše, elementi a_{ij} , $a_{ij} > 0$, $a_{ij} = 1/a_{ji}$, $a_{ii} = 1$, za svako i , AHP matrice poređenja, postaju elementi DEAHP matrice poređenja u Tabeli 3, prilagođenoj za primenu

DEA metoda, u cilju izračunavanja lokalnih prioriteta. Svaki red matrice je je posmatran kao tipičan DMU, a svaka kolona kao jedan izlaz. Osim toga, matrica sadrži i kolonu tzv. dummy tj. fiktivnog ulaza, koji uzima vrednost 1, za svaku DMU, u cilju primene DEA metoda.

R. Ramanathan (2006) dokazuje da se primenom DEA metoda na AHP matricama poređenja, dobijaju objektivizirane vrednosti prioriteta elemenata odlučivanja, čime se umanjuje subjektivnost procena kod AHP metoda, i eliminiše inverzija ranga, do koje dolazi dodavanjem ili izuzimanjem irelevantne alternative, što je karakterističan problem za primenu AHP. Ovako izračunate DEA efikasnosti mogu biti interpretirane kao lokalni prioriteti jedinica odlučivanja. Takođe, DEA se koristi i za agregaciju konačnih prioriteta elemenata odlučivanja. Kada se, u tom smislu, koristi DEA pristup, alternative se posmatraju kao jedinice odlučivanja DMU, a njihovi lokalni prioriteti izračunati u odnosu na svaki kriterijum, kao izlazi, uz korišćenje kolone dummy ulaza (Tabele 4 i 5). S druge strane, za razliku od klasičnog DEA pristupa, koji meri samo relativnu efikasnost, primenom DEAHP metoda, koji, implicitno, uključuje i sposobnost AHP da obuhvati i kvantitativne

Tabela 1 Skala poređenja 1-9

Intenzitet relativne važnosti	Definicija	Objašnjenje
1	Jednaka važnost	Dve aktivnosti jednako doprinose cilju.
3	Umerena važnost jednog u odnosu na drugi	Iskustvo i procena blago favorizuju jednu aktivnost u odnosu na drugu.
5	Esencijalna ili velika važnost	Iskustvo i procena jako favorizuju jednu aktivnost u odnosu na drugu.
7	Demonstrirana važnost	Jedna aktivnost se jako favorizuje, i njena dominacija se demonstrira u praksi.
9	Ekstremna važnost	Dokazi koji favorizuju jednu aktivnost u odnosu na drugu su najvišeg mogućeg reda afirmacije.
2, 4, 6, 8	Srednje vrednosti između dve susedne procene	Kada je potreban kompromis.
Reciprociteti gornjih nenulatih brojeva		Ako jedna aktivnost ima jedan od gornjih brojeva, (na primer, 3), u poređenju sa drugom aktivnošću, onda druga aktivnost ima recipročnu vrednost (tj. 1/3), kada se poredi sa drugom

Tabela 2 Tradicionalna AHP matrica poređenja elemenata po parovima

	Element 1	Element 2	...	Element n
Element 1	1	a_{12}	...	a_{1N}
Element 2	$1/a_{12}$	1	...	a_{2N}
...	...	...	...	...
Element N	$1/a_{1N}$	$1/a_{2N}$	...	1

Izvor: Ramanathan, 2006, 1296

i kvalitativne faktore procesa odlučivanja, dobija se potpunija ocena performansi posmatranih jedinica odlučivanja.

OPIS PROBLEMA I STRUKTURIRANJE DEAHP MODELA ZA OCENU I RANGIRANJE FAKULTETA U REPUBLICI SRBIJI

Vrednovanje fakulteta u RS, primenom AHP metoda, sprovedeno je na primeru 12 fakulteta, sa četiri državna univerziteta (Beograd, Novi Sad, Niš i Kragujevac), prema pet nefinansijskih kriterijuma (Slika 1). Kriterijumi su posmatrani kao ulazni (U_1 , U_2 , U_3) i kao izlazni (I_1 , I_2), shodno činjenici da su isti upotrebljeni i u DEA modelu. Ključni ulazi su broj nastavnika (U_1), broj saradnika (U_2) na fakultetu i broj upisanih studenata (U_3). Kao glavni izlazi dati su broj diplomiranih studenata (I_1) i broj doktorskih disertacija (I_2). Sami fakulteti su izabrani iz oblasti prirodnih, tehničkih i društveno-humanističkih nauka, dok su

Tabela 3 DEAHP matrica poređenja elemenata po parovima i ocene njihove efikasnosti

	Output 1	Output 2	...	Output n	Fiktivni ulaz
DMU ₁	1	a_2	...	a_{1N}	1
DMU ₂	$1/a_{12}$	1	...	a_{2N}	1
...	...	...	...	...	...
DMU _N	$1/a_{1N}$	$1/a_{2N}$	...	1	1

Izvor: Ramanathan, 2006, 1296

Tabela 4 AHP matrica poređenja alternativa u odnosu na kriterijume

	Kriterijum 1	Kriterijum 2	...	Kriterijum J
Alternativa 1	y_{11}	y_{12}	...	y_{1J}
Alternativa 2	y_{21}	y_{22}	...	y_{2J}
...	...	...	...	...
Alternativa N	y_{N1}	y_{N2}	...	y_{NJ}

Izvor: Ramanathan, 2006, 1298

kriterijumi (za primenu AHP metoda), odnosno, ulazi i izlazi (za primenu DEA metoda) izabrani u skladu s dostupnim podacima za akademsku 2013/2014 godinu.

Na osnovu date hijerarhijske strukture, formirana je matrica poređenja kriterijuma AHP modela ocene i rangiranja posmatranih fakulteta i s izvršenim poređenjima prema skali 1-9, prikazana u Tabeli 6.

Strukturiranje DEA modela za ocenu efikasnosti fakulteta u Republici Srbiji

Broj DMU koji treba da se uporedi zavisi od cilja studije i od broja homogenih jedinica čiji učinak u praksi mora da se poredi. Preporučuje se da broj DMU bude veći od proizvoda broja ulaza i izlaza, kako bi se jasno razlikovale efikasna i neefikasna DMU. U konkretnom primeru za ocenu efikasnosti fakulteta u RS odabrano je 12 fakulteta, odnosno, jedinica odlučivanja, 3 ulaza (broj nastavnika, broj saradnika i broj upisanih studenata) i 2 izlaza (broj diplomiranih studenata i broj doktorskih disertacija). Kriterijumi za izbor ovih ulaza i izlaza su sasvim subjektivni. Ne postoji posebno

Tabela 5 DEA pristup oceni efikasnosti alternativa u odnosu na definisane kriterijume

	Kriterijum 1	Kriterijum 2	...	Kriterijum J	Fiktivni ulaz
DMU 1	y_{11}	y_{12}	...	y_{1J}	1
DMU 2	y_{21}	y_{22}	...	y_{2J}	1
...	...	...	...	...	1
DMU N	y_{N1}	y_{N2}	...	y_{NJ}	1

Izvor: Ramanathan, 2006, 1298

Slika 1 AHP hijerarhijska struktura problema ocene i rangiranja

Izvor: Autori

pravilo prilikom utvrđivanja procedura za izbor ulaza i izlaza. Skup ulaza i izlaza za merenje performansi u sektoru obrazovanja je često kritikovan zbog toga što je bio neadekvatan i nepogodan za analizu efikasnosti. Dakle, skup može biti promenljiv u skladu sa zahtevima istraživanja. Jedan od razloga za ovakav odabir ulaza i izlaza jeste i neažurnost podataka i nemogućnost pristupa pojedinim podacima o ulazima i izlazima za posmatrane fakultete.

Tabela 6 Matrica poređenja kriterijuma AHP modela za ocenu i rangiranje fakulteta

Kriterijumi	Izlaz 1	Izlaz 2	Ulaz 1	Ulaz 2	Ulaz 3
Izlaz 1	1	2	1/4	1/3	1
Izlaz 2	1/2	1	1/3	1/2	1/4
Ulaz 1	4	3	1	2	2
Ulaz 2	3	2	1	1	1/2
Ulaz 3	1	4	1/2	2	1

Izvor: Autori

U Tabeli 7, prikazan je strukturirani DEA model za ocenu efikasnosti fakulteta u Republici Srbiji.

Tabela 7 Strukturiranje DEA modela za ocenu efikasnosti fakulteta

Fakultet	Ulaz 1	Ulaz 3	Ulaz 2	Izlaz 1	Izlaz 2
F ₁	52	510	32	424	34
F ₂	100	1350	36	1060	71
F ₃	64	305	49	287	45
F ₄	71	543	12	210	32
F ₅	43	739	18	321	18
F ₆	35	445	24	172	24
F ₇	79	306	40	176	88
F ₈	40	306	25	374	24
F ₉	57	272	41	98	42
F ₁₀	26	204	20	140	6
F ₁₁	35	94	11	35	5
F ₁₂	98	591	71	600	81

Izvor: Informatori o radu fakulteta za akademsku 2013/2014.

U primeni analize obavljanja podataka korišćen je izlazno orijentisan CRS DEA model, koji teži da maksimira izlaz pri datom nivou ulaza, a neefikasna jedinica postaje efikasna kroz povećanje svojih izlaza.

Matematički zapis ovog modela glasi:

$$\max h_k = \sum_{r=1}^s u_r \times y_{rj}$$

$$\sum_{r=1}^s u_r \times y_{rj} - \sum_{i=1}^m v_i \times x_{ij} \leq 0, j = 1, \dots, n$$

$$\sum_{i=1}^m v_i \times x_{io} = 1$$

$$u_r \geq 0, v_i \geq 0$$

gde je:

y_{rj} - vrednost output-a

x_{ij} - vrednost input-a,

u_r - težinski koeficijent output-a y_{rj} ,

v_j - težinski koeficijent input-a x_{ij} ,

$r = 1, 2, \dots, s$ - broj ostvarenih proizvoda,

$i = 1, 2, \dots, m$ - broj korišćenih resursa,

$j = 1, 2, \dots, n$ - broj DMU.

U posmatranom problemu, za fakultet F_1 , odgovarajući CRS DEA linearni model glasi:

$$\max h_k = 424 y_1 + 34 y_2$$

Uz sistem ograničavajućih uslova:

$$52 x_1 + 32 x_2 + 510 x_3 = 1$$

$$424 y_1 + 34 y_2 - (52 x_1 + 32 x_2 + 510 x_3) \leq 0$$

$$1060 y_1 + 71 y_2 - (100 x_1 + 36 x_2 + 1350 x_3) \leq 0$$

$$287 y_1 + 45 y_2 - (64 x_1 + 49 x_2 + 305 x_3) \leq 0$$

$$210 y_1 + 32 y_2 - (71 x_1 + 12 x_2 + 543 x_3) \leq 0$$

$$321 y_1 + 18 y_2 - (43 x_1 + 18 x_2 + 739 x_3) \leq 0$$

$$172 y_1 + 24 y_2 - (35 x_1 + 24 x_2 + 445 x_3) \leq 0$$

$$176 y_1 + 88 y_2 - (79 x_1 + 40 x_2 + 306 x_3) \leq 0$$

$$374 y_1 + 24 y_2 - (40 x_1 + 25 x_2 + 306 x_3) \leq 0$$

$$98 y_1 + 42 y_2 - (57 x_1 + 41 x_2 + 272 x_3) \leq 0$$

$$140 y_1 + 6 y_2 - (26 x_1 + 20 x_2 + 204 x_3) \leq 0$$

$$35 y_1 + 5 y_2 - (35 x_1 + 11 x_2 + 94 x_3) \leq 0$$

$$600 y_1 + 81 y_2 - (98 x_1 + 71 x_2 + 591 x_3) \leq 0$$

$$y_1, y_2 \geq 0$$

$$x_1, x_2, x_3 \geq 0$$

odgovarajući modeli se formiraju na identičan način i za ostale jedinice odlučivanja, odnosno, fakultete.

REZULTATI PRIMENE AHP, DEA I DEAHF METODA

Rezultati primene AHP metoda

Korišćenjem *software* paketa *Superdecision* izračunati su težinski koeficijenti kriterijuma, a na osnovu njih konačni prioriteti alternativa. U Tabeli 8 može se videti da najveći prioritet i rang 1 ima kriterijum Broj nastavnika (0.368173), a najmanji rang 5 ima kriterijum Broj doktorskih disertacija (0.078690).

Prikaz konačnog ranga alternativa AHP modela za ocenu i rangiranje fakulteta primenom *software* paketa *Superdecision* dat je u Tabeli 9. Prema dobijenim rezultatima može se uočiti da najbolji rang ima Fakultet 12, a na drugom mestu je Fakultet 2.

U slučaju da u procesu procena i poređenja učestvuje više eksperata, odnosno, donosilaca odluka, moguće je koristiti geometrijsku sredinu kao način za

Tabela 8 Težinski koeficijenti i rang kriterijuma AHP modela za ocenu i rangiranje fakulteta

Kriterijum	Težinski koeficijenti	Rang
Izlaz 1	0.126346	4
Izlaz 2	0.078690	5
Ulaz 1	0.368173	1
Ulaz 2	0.193262	3
Ulaz 3	0.233529	2

Indeks konzistentnosti: CR = 0,0742

Izvor: Autori

Tabela 9 Prioriteti i konačan rang alternativa AHP modela za ocenu i rangiranje fakulteta

Alternative	Ukupno	Normalizovano	Idealizovano	Rang
Fakultet 1	0.0394	0.0788	0.3519	5
Fakultet 2	0.1107	0.2214	0.9886	2
Fakultet 3	0.0414	0.0829	0.3699	4
Fakultet 4	0.0360	0.0721	0.3219	6
Fakultet 5	0.0352	0.0704	0.3144	7
Fakultet 6	0.0185	0.0370	0.1654	9
Fakultet 7	0.0445	0.0890	0.3972	3
Fakultet 8	0.0170	0.0340	0.1518	10
Fakultet 9	0.0295	0.0590	0.2633	8
Fakultet 10	0.0087	0.0174	0.0775	11
Fakultet 11	0.0070	0.0140	0.0626	12
Fakultet 12	0.1120	0.2240	1.0000	1

Izvor: Autori

kombinovanje i objektivizaciju procena (Saaty & Peniwati, 2008):

$$w_i = \sqrt[k]{\prod_{k=1}^K w_{ik}} \quad \forall i$$

gde je w_i , konačna težina i -tog faktora, a w_{ik} , relativna težina i -tog elementa, izračunata na osnovu procena k -tog evaluatora.

Rezultati primene DEA metoda

Za ocenu efikasnosti fakulteta u RS upotrebljen je ulazno orijentisan CCR model sa konstantnim prinosom na obim (Constant Return to Scale - CRS). Rezultati koji su predstavljeni u Tabeli 10, dobijeni su na osnovu tri ulaza (broj nastavnika, broj saradnika, broj upisanih studenata) i dva izlaza (broj diplomiranih studenata, broj doktorskih disertacija). S obzirom da je u literaturi postoje brojne dileme oko odnosa DMU i broja ulaznih i izlaznih veličina, predlaže se da broj DMU bude barem dva puta veći od zbira ulaznih i izlaznih veličina (2+1). Imajući u vidu da predloženi model ima ukupno pet promenljivih (3 ulazne i 2 izlazne), minimalan broj jedinica odlučivanja je 10. U ovom modelu je korišćeno 12 DMU, odnosno, 12

fakulteta u RS. Efikasnost je određena primenom *software* paketa *DEAFrontier*.

Na osnovu rezultata u Tabeli 11, može se zaključiti da su fakulteti F2, F4, F7 i F8 relativno efikasni, odnosno, 4 jedinice odlučivanja formiraju efikasnu obvojniciu. Njihova efikasnost je 1, što znači da ne poseduju „viškove“ u ulaznim, niti „manjkove“ u izlaznim promenljivim. Ostali fakulteti se mogu smatrati relativno neefikasnim.

Rezultati primene DEAHP metoda

U skladu sa sugestijama R. Ramanathan-a (2006), DEA metod se može koristiti za deriviranje objektiviziranih lokalnih prioriteta elemenata odlučivanja. Kako su to, takođe, pokazali B. D. Royendegh i S. Erol (2009), moguće je formirati i primeniti efikasan model za rangiranje jedinica odlučivanja sa višestrukim izlazim i ulazima, koristeći DEA metod u kombinaciji sa AHP/ANP metodima. U Tabeli 12, data je matrica poređenja kriterijuma u kojoj su ulazne vrednosti procene nastale kao rezultat AHP poređenja kriterijuma prema skali 1-9. Ove procene se nadalje, kako sugeriše R. Ramanathan (2006), mogu koristiti kao vrednosti izlaza u odgovarajućem DEA modelu (Tabela 13), kojem je, takođe, dodata i kolona vrednosti fiktivnog ulaza, kao uslov za formiranje i primenu DEA modela. Primenom DEA metode na tako strukturiran problem, dobijene su relativne efikasnosti ulaza i izlaza, odnosno, izabranih kriterijuma, koje, međutim, nisu od značaja za dalju primenu DEAHP metoda, s obzirom da njih i njihove relativne važnosti nije neophodno uzeti u obzir prilikom formiranja DEAHP matrice poređenja i izračunavanja DEAHP relativnih efikasnosti alternativa. Tabela 14 pokazuje DEAHP matricu poređenja kriterijuma, dok Tabela 15 predstavlja matricu poređenja jedinica odlučivanja - alternativa u odnosu na Izlaz 1. Ulazne vrednosti su procene nastale kao rezultat poređenja parova alternativa - fakulteta u AHP modelu. Tabela 15 uobičajeno, sadrži i kolonu vrednosti fiktivnog ulaza, kao i kolone izlaza u cilju primene DEAHP modela. U Tabeli 16, date su izračunate DEAHP relativne efikasnosti jedinica odlučivanja, odnosno njihovi lokalni prioriteti, u odnosu na Izlaz 1.

Tabela 10 Efikasnost i optimalne vrednosti težinskih koeficijenata input-a i output-a izlazno orijentisanog CRS DEA modela

DMU No.	DMU Name	Efikasnost	Ulaz 1	Ulaz 2	Ulaz 3	Izlaz 1	Izlaz 2
1	F1	0.90949	0.01453	0.00000	0.00048	0.00115	0.01241
2	F2	1.00000	0.00000	0.00725	0.00055	0.00069	0.00383
3	F3	0.95397	0.00000	0.00000	0.00328	0.00224	0.00692
4	F4	1.00000	0.00000	0.05362	0.00066	0.00101	0.02464
5	F5	0.70426	0.02326	0.00000	0.00000	0.00219	0.00000
6	F6	0.75553	0.02857	0.00000	0.00000	0.00113	0.02339
7	F7	1.00000	0.00000	0.00000	0.00327	0.00000	0.01136
8	F8	1.00000	0.00000	0.00000	0.00327	0.00223	0.00690
9	F9	0.67119	0.01754	0.00000	0.00000	0.00069	0.01436
10	F10	0.57332	0.03160	0.00000	0.00088	0.00410	0.00000
11	F11	0.36652	0.00000	0.00000	0.01064	0.00726	0.02247
12	F12	0.99293	0.00851	0.00000	0.00028	0.00067	0.00727

Izvor: Autori

Relativne efikasnosti alternativa-fakulteta, posmatrane u odnosu na izlaz 1, prikazane su u Tabeli 16. Na identičan način se mogu formirati matrice poređenja alternativa u odnosu na Izlaz 2, kao i ostale ulaze,

Tabela 11 Efikasnost i rang fakulteta izračunati primenom izlazno orijentisanog CRS DEA modela

Fakultet	Efikasnost	Rang
F1	0.90949	7
F2	1.00000	1
F3	0.95397	6
F4	1.00000	1
F5	0.70426	9
F6	0.75553	8
F7	1.00000	1
F8	1.00000	1
F9	0.67119	10
F10	0.57332	11
F11	0.36652	12
F12	0.99293	5

Izvor: Autori

nakon čega se primenom DEA metoda određuju lokalni prioriteti, odnosno, relativne efikasnosti posmatranih jedinica odlučivanja.

Pošto su izračunati lokalni prioriteti alternativa u odnosu na sve pojedinačne ulaze i izlaze, sledeći korak je formiranje DEAHP matrice poređenja alternativa (Tabela 17) u odnosu na sve kriterijume istovremeno, pri čemu ulazne vrednosti matrice predstavljaju lokalni prioriteti alternativa izračunati u odnosu na pojedinačne kriterijume, a u tabeli je uobičajeno i kolona vrednosti fiktivnog ulaza u cilju primene

Tabela 12 Matrica poređenja kriterijuma AHP modela za ocenu i rangiranje fakulteta

Kriterijumi	Izlaz 1	Izlaz 2	Ulaz 1	Ulaz 2	Ulaz 3
Izlaz 1	1	2	1/4	1/3	1
Izlaz 2	1/2	1	1/3	1/2	1/4
Ulaz 1	4	3	1	2	2
Ulaz 2	3	2	1	1	1/2
Ulaz 3	1	4	1/2	2	1

Izvor: Autori

Tabela 13 DEAHP matrica poređenja za ocenu efikasnosti kriterijuma

DMU	I1	O1	O2	O3	O4	O5
I1	1	1	2	0.250	0.333	1
I2	1	0.5	1	0.333	0.5	0.25
O1	1	4	3	1	2	2
O2	1	3	2	1	1	0.5
O3	1	1	4	0.5	2	1

Izvor: Autori

Tabela 14 Efikasnost kriterijuma izračunata primenom DEAHP metoda

DMU No.	DMU name	Efikasnost
1	I1	0.60000
2	I2	0.70000
3	O1	1.00000
4	O2	1.00000
5	O3	1.00000

Izvor: Autori

Tabela 16 DEAHP relativna efikasnost alternativa u odnosu na Izlaz 1

DMU No.	DMU name	Efikasnost
1	F1	0.87500
2	F2	1.00000
3	F3	0.66667
4	F4	0.55556
5	F5	0.77778
6	F6	0.44444
7	F7	0.66667
8	F8	0.88889
9	F9	0.44444
10	F10	0.44444
11	F11	0.11111
12	F12	1.00000

Izvor: Autori

DEA metoda. Konačni prioriteti alternativa, odnosno, njihove DEAHP relativne efikasnosti, prikazane su u Tabeli 18, iz koje je vidljivo da su fakulteti F1, F2, F3, F5,

Tabela 15 DEAHP matrica poređenja alternativa u odnosu na Izlaz 1

DMU	I1	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12
F1	1	1	0.5	4.000	5	3	5	5	3	7	5	7	0.333
F2	1	2	1	6	7	5	8	8	5	8	7	9	4
F3	1	0.2	0.167	1	3	0.5	4	4	0.25	4	3	6	0.2
F4	1	0.2	0.143	0.333	1	0.333	4	4	0.333	4	3	5	0.2
F5	1	0.333	0.2	2	3	1	3	3	0.333	5	4	7	0.2
F6	1	0.2	0.125	0.25	0.25	0.333	1	0.5	0.2	3	2	4	0.143
F7	1	0.2	0.125	0.25	0.25	0.333	2	1	0.25	4	3	6	0.143
F8	1	0.333	0.2	4	3	3	5	4	1	7	6	8	0.25
F9	1	0.143	0.125	0.25	0.25	0.2	0.333	0.25	0.143	1	0.5	4	0.125
F10	1	0.2	0.143	0.333	0.333	0.25	0.5	0.333	0.167	2	1	4	0.125
F11	1	0.143	0.111	0.167	0.2	0.143	0.25	0.167	0.125	0.25	0.25	1	0.111
F12	1	3	0.25	5	5	5	7	7	4	8	8	9	1

Indeks konzistentnosti: CR = 0,09886

Izvor: Autori

Tabela 17 Lokalni prioriteti alternativa u odnosu na kriterijume (izlaze i ulaze)

DMU	I1	C1	C2	C3	C4	C5
F1	1	0.55556	0.66667	0.833	0.875	1
F2	1	1	0.66667	1	1	1
F3	1	0.77778	1	0.44444	0.66667	0.66667
F4	1	0.77778	0.11111	0.88889	0.55556	0.5
F5	1	0.44444	0.33333	1	0.77778	0.22979
F6	1	0.33333	0.44444	0.75	0.44444	0.26047
F7	1	0.875	0.66667	0.5	0.66667	1
F8	1	0.44444	0.44444	0.11111	0.88889	0.33617
F9	1	0.57143	0.66667	0.55556	0.44444	1
F10	1	0.11111	0.33333	0.44444	0.44444	0.12077
F11	1	0.22222	0.11111	0.25	0.11111	0.12077
F12	1	1	1	0.88889	1	1

Izvor: Autori

F7, F9 i F12, relativno efikasni, dok su ostali relativno neefikasni, pri čemu je fakultet F11 najslabije rangiran. Konačno, u Tabeli 19, dat je uporedni prikaz prioriteta alternativa, odnosno njihovih relativnih efikasnosti¹, izračunatih primenom sva tri metoda. Uočljivo je da

Tabela 19 Uporedna analiza prioriteta alternativa, dobijenih primenom AHP, DEA i DEAHP metoda

	AHP efikasnosti	DEA prioriteti (efikasnosti)	DEAHP prioriteti
F ₁	0.3519	0.90949	1.00000
F ₂	0.9886	1.00000	1.00000
F ₃	0.3699	0.95397	1.00000
F ₄	0.3219	1.00000	0.88889
F ₅	0.3144	0.70426	1.00000
F ₆	0.1654	0.75553	0.75000
F ₇	0.3972	1.00000	1.00000
F ₈	0.1518	1.00000	0.88889
F ₉	0.2633	0.67119	1.00000
F ₁₀	0.0775	0.57332	0.45454
F ₁₁	0.0626	0.36652	0.25000
F ₁₂	1.0000	0.99293	1.00000

Izvor: Autori

fakulteti F2 i F12, imaju slaganje vrednosti prioriteta izračunatih primenom sva tri metoda, što samo potvrđuje činjenicu da su to fakulteti s najboljim performansama.

Tabela 18 Konačni prioriteti alternativa izračunati DEAHP pristupom

DMU No.	DMU name	Efikasnost
1	F1	1.00000
2	F2	1.00000
3	F3	1.00000
4	F4	0.88889
5	F5	1.00000
6	F6	0.75000
7	F7	1.00000
8	F8	0.88889
9	F9	1.00000
10	F10	0.45454
11	F11	0.25000
12	F12	1.00000

Izvor: Autori

ZAKLJUČAK

U radu je prezentovan hibridni DEAHP metod u vrednovanju performansi 12 državnih fakulteta u Republici Srbiji. Ideja je bila da se na sveobuhvatan način, kroz integrisanu i kombinovanu primenu DEA i AHP metoda, dobije potpunija i objektivnija ocena performansi posmatranih fakulteta i izvrši njihovo rangiranje. Krajnji cilj rada bio je unapređenje procesa vrednovanja institucija visokog obrazovanja u RS, primenom metoda višekriterijumske analize.

Predloženi pristup kombinovanja Analitičkog hijerarhijskog procesa, kao metoda za podršku odlučivanju u uslovima kompleksnosti i neizvesnosti, i robusnih neparametarskih metoda kao što je Analiza obavljanja podataka, obezbeđuje fleksibilan, sistematičan i objektivan okvir za sveobuhvatno (apsolutno i relativno), merenje efikasnosti i ocenu

performansi i, implicitno, pouzdanu osnovu za donošenje kvalitetnih strategijskih odluka u visokom obrazovanju. Omogućujući simultano obuhvatanje i nefinansijskih pokazatelja, uz mogućnost uključivanja ne samo kvantitativnih, već i kvalitativnih faktora, i njihovo kombinovanje (kroz AHP), predloženi pristup u značajnoj meri umanjuje često prisutne subjektivnost i pristrasnost, u merenju i oceni organizacionih performansi. U teorijsko-metodološkom smislu, ostaju neke dileme vezane za funkcionisanje DEAHP metoda u slučaju nekonzistentnih matrica procena (Ramanathan, 2006) što se, međutim, može verifikovati ili osporiti budućim empirijskim istraživanjima. Korisno bi bilo i izvršiti analizu osetljivosti rešenja i proveriti da li i kako promena relativne važnosti izabranih kriterijuma kod AHP metoda utiče na rang alternative i kakve to posledice može imati na integrisanu primenu sa DEA metodom, kako generalno, tako i u konkretnom slučaju.

Na osnovu dobijenih rezultata, može se zaključiti da su potencijalno velike mogućnosti primene naučno utemeljenih metoda i modela višekriterijumske analize naročito u oblasti visokog obrazovanja, jer se stvaraju bolje pretpostavke za donošenje kvalitetnih menadžmentskih odluka koje imaju dugoročne posledice za društvo. Ako se posmatra u širem društvenom kontekstu, rezultati realizovanog istraživanja, mogu doprineti unapređenju sistema upravljanja i rukovođenja ustanovama visokog obrazovanja, i biti značajan indikator daljem razvoju visokoškolskih ustanova i srpskog društva u celini. Takođe, dobijeni rezultati mogu predstavljati bazu za buduća istraživanja, u kombinaciji i kroz poređenje sa rezultatima dobijenih primenom drugih metoda višekriterijumskog odlučivanja, kako bi se našla najbolja kombinacija metoda za ocenu i rangiranje ne samo visokoškolskih institucija, u kontekstu kontinuiranog procesa reformi visokog obrazovanja, već i drugih neprofitnih organizacija u RS.

U suštinskom smislu, za sprovedeni postupak ocene efikasnosti i merenja performansi posmatranih fakulteta, vezana su određena ograničenja, a najvažnije se odnosi na činjenicu da je za potrebe analize uzet relativno mali broj ulaza i izlaza modela, te da su izostavljeni oni koji se odnose na naučnoistraživačku i finansijsku komponentu, kao izuzetno

značajne dimenzije funkcionisanja posmatranih visokoobrazovnih institucija. Uključivanjem ovih faktora u analizu, dobila bi se realnija, višedimenzionalna ocena performansi fakulteta, što otvara prostor za nove interpretacije dobijenih rezultata, korelaciona analizu, analizu osetljivosti rešenja i dalja istraživanja u tom pravcu. Osim toga, zbog nedovoljne ažuriranosti i transparentnosti podataka, i pored godišnjih obaveza o publikovanju informatora o radu fakulteta, ne postoji mogućnost formiranja dovoljno dugih vremenskih serija podataka, koje bi omogućile i razne ekonometrijske analize i poređenje ostvarenih performansi fakulteta i po periodima.

ENDNOTA

- 1 Prioriteti u AHP modelu mogu biti interpretirani na različite načine, u zavisnosti od konteksta. U ovom slučaju, imaju značenje efikasnosti. Efikasnosti alternativa izračunate AHP metodom su preuzete iz kolone „idealizovano“, a dobijaju se deljenjem svih pojedinačnih vrednosti prioriteta najvećom vrednošću, u koloni „normalizovanih vrednosti“.

REFERENCE

- Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: A data envelopment analysis. *Economics of Education Review*, 22(1), 89-97, doi: 10.1016/S0272-7757(01)00068-1.
- Antreas, D. A., & Estelle, S. (1997). Assessing the comparative efficiency of Higher education institutions in the UK by means of data envelopment analysis. *Education Economics*, 5(2), 117-134, doi: 10.1080/09645299700000011.
- Aruldoss, M., Lakshmi, T. M., & Venkatesan, V. P. (2013). A survey on multicriteria decision making methods and its applications. *American Journal of Information Systems*, 1(1), 31-43, doi: 10.12691/ajis-1-1-5.
- Do, Q. H., & Chen, J-F. (2014). A hybrid fuzzy AHP-DEA approach for assessing university performance. *WSEAS Transactions on Business and Economics*, 11, 386-397.
- Ehie, I. C., & Karathanos, D. (1994). Business faculty performance evaluation based on the new AACSB accreditation standards. *Journal of Education for Business* 69(5), 257-262, doi: 10.1080/08832323.1994.10117695.

- Ghosh, D. N. (2011). Analytic hierarchy process & TOPSIS method to evaluate faculty performance in engineering education. *Dipendra Nath Ghosh et al UNIASCIT*, 1(2), 63-70.
- Grandzol, J. R. (2005). Improving the faculty selection process in higher education: A case for the analytic hierarchy process. *IR Applications 6*, Bloomsburg University of Pennsylvania, 1-13, ERIC Number: ED504373.
- Ishizaka, A., & Labib, A. (2011). Review of the main developments in the analytic hierarchy process. *Expert Systems with Applications*, 38(11): 14336-14345, doi: 10.1016/j.eswa.2011.04.143
- Johnes, J. (1996). Performance assessment in higher education in Britain. *European Journal of Operational Research*, 89(1), 18-33, doi: 10.1016/S0377-2217(96)90048-X
- Johnes, J. (2006). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, 25(3), 273-288, doi: 10.1016/j.econedurev.2005.02.005
- Kao, C., & Hung, H. T. (2008). Efficiency analysis of university departments: An empirical study. *Omega*, 36(4), 653-664, doi: 10.1016/j.omega.2006.02.003
- Kong, W. H., & Fu, T. T. (2012). Assessing the performance of business colleges in Taiwan using data envelopment analysis and student based value-added performance indicators. *Omega*, 40(5), 541-549, doi: 10.1016/j.omega.2011.10.004
- Nazarko, J., & Šaparauskas, J. (2014). Application of DEA method in efficiency evaluation of public higher education institutions. *Tehnological and Economic Development of Economy*, 20(1), 25-44, doi: 10.3846/20294913.2014.837116.
- Ramanathan, R. (2006). Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. *Computers & Operations Research*, 33, 1289-1307, doi: 10.1016/j.cor.2004.09.020
- Royendegh, B. D., & Erol, S. (2009). A DEA-ANP hybrid algorithm approach to evaluate a university's performance. *International Journal of Basic & Applied Sciences*, 9(10), 115-129.
- Saaty, T. L. (1980). *The Analytic Hierarchy Process*. New York, NY: McGraw-Hill.
- Saaty, T., & Kearns, K. (1985). *Analytical Planning: The Organization of Systems*. Pittsburgh: Pergamon Press.
- Saaty, T., & Peniwati K. (2008). *Group decisionmaking: drawing out and reconciling differences*. 1, RWS, Pittsburgh.
- Saad, G. (2001). Strategic performance evaluation: descriptive and prescriptive analysis. *Industrial management and Data system*, 101(8), 390-399, <http://dx.doi.org/10.1108/EUM000000000006169>
- Sipahi, S., & Timor, M. (2010). The Analytic hierarchy process and Analytic Network Process: an overview of applications. *Management decision*, 48(5), 775-808, <http://dx.doi.org/10.1108/00251741011043920>
- Subramanian, N., & Ramanathan, R. (2012). A review of applications of Analytic Hierarchy Process in operations management. *Int. J. Production Economics*, 138, 215-241, doi:10.1016/j.ijpe.2012.03.036
- Tangen, S. (2005). Analysing the requirements of performance measurement systems. *Measuring Business Excellence* 9(4), 46-54, <http://dx.doi.org/10.1108/13683040510634835>
- Tummala, V. M. R., & Sanchez, P. P. (1988). Evaluating faculty merit awards by analytic hierarchy process. *Modeling, Simulation and Control C: Environmental, Biomedical, Human and Social Systems* 11(4), 1-13.
- Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal Of Operational Research*, 169(1), 1-29, doi:10.1016/j.ejor.2004.04.028
- Ying, C. Ng., & Li, S. K. (2000). Measuring the research performance of Chinese Higher education institutions: an application of Data envelopment analysis. *Education Economics*, 8(2), 139-156, doi: 10.1080/096452900410712.
- <http://www.superdecisions.com/~saaty/.../SuperDecisionsManualMar2005.doc/>

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THE INTEGRATED APPLICATION OF THE AHP AND THE DEA METHODS IN EVALUATING THE PERFORMANCES OF HIGHER EDUCATION INSTITUTIONS IN THE REPUBLIC OF SERBIA

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The measurement and evaluation of performance are critical for the efficient and effective functioning of the economic system, because this allows for the analysis of the extent to which the defined objectives are achieved. Organizational performance is measured by different methods, both quantitative and qualitative. Many of the known methods for the evaluation and measurement of organizational performance take into account only financial indicators, while ignoring the non-financial ones. The integration of both indicators, through the combined application of multiple methods and the comparison of their results, should provide a more complete and objective picture of organizational performance. The Analytic Hierarchy Process (AHP) is a formal framework for solving complex decision-making problems, as well as a systemic procedure for the hierarchical presentation of the problem elements. The Data Envelopment Analysis (DEA) is a non-parametric approach based on linear programming, which allows for the calculation of the efficiency of decision-making units within a group of organizations. The work is an illustration of the method and framework of the combined use of the multi-criteria analysis methods for the measurement and evaluation of the performance of higher education institutions in the Republic of Serbia. The advantages of this approach are reflected in overcoming the shortcomings of a partial application of the AHP and the DEA methods by utilizing a new, hybrid, DEAHP (Data Envelopment Analytic Hierarchy Process) method. Performance evaluation through an integrated application of the AHP and the DEA methods provides more objective results and more reliable solutions to the observed problem, thus creating a valuable information base for high-quality strategic decision making in higher education institutions, both at the national level and at the level of individual institutions.

Keywords: multi-criteria analysis, analytic hierarchy process, data envelopment analysis, organizational performance, higher education

JEL Classification: C44, C61, D81, I23