University of Belgrade, Technical Faculty in Bor

29th International Conference Ecological Truth & Environmental Research

EcoTER'22

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Editor
Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia

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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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EVNIRONMENTAL PERFORMANCE CLASSIFICATION OF BALKAN COUNTRIES BASED ON TOPSIS-SORT METHODOLOGY

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Abstract

This paper analyzes the values of the Environmental Performance Index (EPI) in 2020 for the Balkan countries. The aim of the research is to use the TOPSIS-Sort methodology, based on a sample of ten countries, in order to classify them into those with acceptable (Class 1) and those with less acceptable (Class 2) EPI values in the field of environmental policy. A sorting procedure has been realized in relation to the reference value determined in accordance with the data of countries. In addition, a sensitivity analysis was performed by changing the benchmark used to classify countries. The results of the conducted analyzes show that under strict criteria for the formation of Class 1, no country can be classified in the class of belonging. Only during the conducted sensitivity analysis and less strict formation of Class 1 do the countries join the belonging class. Greece and Slovenia are the first to be classified in Class 1.

Keywords: EPI, TOPSIS, environmental performance, sensitivity analysis, Balkan countries

INTRODUCTION

Environmental protection is an imperative of the modern age. In this regard, there is a need to develop and improve the environmental index in order to facilitate environmental decision-making [1]. Modern methods of monitoring performance in the field of environmental protection strive to obtain qualitative and quantitative data, which will direct decision-makers to the weaknesses of the monitoring and environmental protection system. One such metric is the Environmental Performance Index (EPI).

The EPI aims to quantify the key outcomes of the implemented environmental policy [2]. This index has been used since 2006, when it was developed by the World Economic Forum, Yale University and Columbia University [3]. The most recent data on the values of EPI are from 2020. The report on the EPI index for 2020 provides a summary of the state of sustainability around the world based on measured data, using 32 indicators classified into 11 categories [4].

A review of the literature indicates that the researchers' efforts to date have focused on processing the EPI index using multicriteria decision-making methods (MCDM). In 2012 Ismail and Abdullah proposed the Analytical Hierarchy Process (AHP) methodology for ranking the environmental performance of Southeast Asian countries. Subjecting to this methodology the EPI values of certain countries, the authors came to the conclusion that different weights of criteria, obtained by applying the Satie scale, led to a different ranking of countries according to the value of this index [5].

In 2017 Abdullah ranked Southeast Asia countries using the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), considering eleven countries (as alternatives) and ten environmental policy areas (as criteria), determining the weights of the criteria using the entropy method [6]. A similar study was conducted by Mohaghar *et al*. in 2019, when they used the TOPSIS method to rank OECD Countries according to the value of the EPI index from the 2016 report, according to nine environmental policy areas. The weights of the criteria were also determined using the entropy method [7].

On the other hand, Digkoglou and Papathanasiou used the Preference Ranking Organization Method for Enriched Evaluation (PROMETHEE) to rank 28 European Union countries based on two criteria (Environmental Health and Ecosystem Vitality) for the period 2006–2018, using the same weight of criteria [8].

The weights of the criteria used to determine the final EPI rank of countries have also been analyzed and it has been noted that additional attention should be paid to the process of determining the importance of indicators [9]. On the other hand, the author Pinar analysed the weights of the criteria (indicators) used to generate the EPI score and gave his critical view of how important the criterion should be, based on the analysis of stochastic dominance [10]. This points to the need for a more consistent determination of the importance of the criteria used to rank countries based on EPI index values.

Having in mind the above, it can be concluded that MCDM methods are applicable in the ranking of countries based on the value of environmental policy areas used by the EPI methodology. The aim of this research is to examine the possibility of applying another of this group of methods - TOPSIS-Sort methodology, for the purpose of classifying the Balkan countries according to their environmental performance.

MATERIALS AND METHODS

TOPSIS-Sort methodology

The following section gives a brief explanation of the proposed TOPSIS-Sort model. The sorting problem involves the assignment of a set of alternatives $A=\{a_1, a_2, \ldots, a_m\}$ into K predefined ordered classes $C_1, C_2, \ldots, C_K$ [11] by taking in the consideration conflict criteria $F=\{g_{1,\ldots},g_n\}$. For that purpose it can be used several MCDM methods including TOPSIS-Sort methodology. Algorithm details the TOPSIS-Sort procedure, adopted by Sabokbar *et al*. [12] in 2016. There are several steps according to this algorithm:

Step 1: Determine the Decision Matrix $X = [x_{i,j}]m\times n$

Step 2: Establish a Profile limit (*Pl)*

Step 3: Establish a new Decision Matrix $M=[Mi,j](m+1)\times n$ formed by the set of alternatives and aditional Profile limit.

Step 4: Normalize Decision Matrix M, by trasnforming it in to a form of matrix $R = [r_{i,j}](m+ 1)\times n$ by the equation:

$$r_{ij} = \frac{M_{ij}}{\max\limits_{1\le i\le(m+1)} M_{ij}} \qquad (1)$$

where: $i=1, \ldots, (m+1); j=1, \ldots, n$

Step 5. Calculate the weighted nnomalized decision matrix $V = [v_{ij}]m \times n:$.

$$v_{ij} = w_j \cdot r_{ij}; i = 1,2\ldots, m+1; j = 1,2,\ldots, n \tag{2}$$

Where w_j represents weight of corresponding criterion Fj, and:

$$\sum_{j=1}^{n} w_j = 1; j = 1,2,\ldots, n \tag{3}$$

Step 6.: Determine the ideal (v^*) and anti-ideal (v^-) solutions.

$$v^* = [v_1^*, v_2^*, \ldots, v_n^*]; v_j^* \begin{cases} \max\limits_{1 \le i \le m+1} v_j; g_j \in F^+; j = 1,2,\ldots, n \\ \min\limits_{1 \le i \le m+1} v_j; g_j \in F^-; j = 1,2,\ldots, n \end{cases} \tag{4}$$

$$v^- = [v_1^-, v_2^-, \ldots, v_n^-]; v_j^- \begin{cases} \min\limits_{1 \le i \le m+1} v_j; g_j \in F^+; j = 1,2,\ldots, n \\ \max\limits_{1 \le i \le m+1} v_j; g_j \in F^-; j = 1,2,\ldots, n \end{cases} \tag{5}$$

Step 7.: Calculate the Euclidian distances of each alternative as well Profile limit (Pl) for the ideal and antiideal solutions.

$$d_{ai}^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}; i = 1,2,\ldots, m+1 \tag{6}$$

$$d_{ai}^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}; i = 1,2,\ldots, m+1 \tag{7}$$

Step 8.: Calculate the closeness coefficient $Cl(a_i)$ of each alternative to the ideal solution based on the distances obtained in the previous Step 7.

$$Cl(a_i) = \frac{d_{ai}^-}{d_{ai}^* + d_{ai}^-}; i = 1,2,\ldots, m \tag{8}$$

Step 9: Calculate the closeness coefficient Cl(Pl) of the Profile limit (Pl) to the ideal solution based on the distances obtained in the Step 7.

Step 10: Classify the alternatives a_i (i=1,2,...,m) into the Class 1 or Class 2 by performing comparisons between closeness coefficients $Cl(a_i)$ and Cl(Pl), according to the following rules:

$$\begin{aligned} &a_i \in Class\_1 \quad iff \quad Cl(a_i) \ge Cl(Pl) \\ &or \\ &a_i \in Class\_2 \quad iff \quad Cl(a_i) < Cl(Pl) \\ &i = 1,2,\ldots,m \end{aligned} \tag{9}$$

Research data

According to the 2020 report [4], the calculation of the EPI index is based on eleven indicators. However, in the case of the Balkan countries, there is a lack of certain data. In order to avoid the risk of making insufficiently reliable conclusions, the authors excluded two criteria from the further analysis (Waste Management and Fisheries), in which are significant number of missing values. The final data set consisted of the values of nine categories of environmental performance (Air Quality, Sanitation and Drinking Water, Heavy Metals, Biodiversity, Ecosystem Services, Climate Change, Pollution Emissions, Agriculture and Water Resources) for ten countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, Northern Macedonia, Romania, Serbia and Slovenia) located on the Balkan Peninsula. In the next step, all the considered criteria were given equal weight. Table 1 shows the initial decision matrix, which includes the EPI index values for the Balkan countries evaluated in 2020.

Table 1 *The EPI index values for Balkan countries in 2020*

	Air Quality	***Sanitation and Drinking Water***	***Heavy Metals***	***Biodiversity***	***Ecosystem Services***	***Climate Change***	***Pollution Emissions***	***Agriculture***	***Water Resources***
Albania	41.2	54	46.1	68.2	43.2	56.8	100	37.6	2.7
B&H	31.6	61.4	42.9	32.9	53.4	57.5	78.1	25.1	1.1
Bulgaria	33	68.3	45.8	77.7	41.4	69.5	100	63.6	13.9
Croatia	50.8	70.2	75.1	82.6	40.3	70	90.8	65.4	51.7
Greece	67.5	98.2	69.4	72.6	43.9	66.5	78.9	52.6	81.7
Montenegro	33.9	65.6	65.2	36.6	44.3	65.5	85.2	19.2	8.4
N. Macedonia	26.5	61.1	46.7	62.1	42.3	75.2	100	40.9	0.9
Romania	43.6	55.9	51.4	85	40.9	84.6	100	65.7	30.4
Serbia	33.6	65.5	51.1	57.54	45.8	68.1	89	69.9	1.7
Slovenia	60.9	74.7	88.1	86.4	37.1	75.2	90	47	89.1
Pl (Profile Limit)	51.1	80.52	70.02	65	46.88	73.48	91.24	49.62	53.82
wj	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**

Data for the virtual alternative Pl (*Profile Limit*) were obtained according to formula 10, and in Table 1 the values for c = 40% are shown. The value of the Profile limit alternative was subjected to sensitivity analysis by changing the coefficient c (%).

$$Pl_j = \begin{cases} \max\limits_j X_{ij} - (\max\limits_j X_{ij} - \min\limits_j X_{ij}) \cdot c[\%];\ g_j \in F^+;\ i = 1,2,\ldots,\ m;\ j = 1,2,\ldots,\ n \\ \min\limits_j X_{ij} + (\max\limits_j X_{ij} - \min\limits_j X_{ij}) \cdot c[\%];\ g_j \in F^-;\ i = 1,2,\ldots,\ m;\ j = 1,2,\ldots,\ n \end{cases} \quad (10)$$

RESULTS AND DISCUSSION

The results obtained by processing the data using the TOPSIS-Sort method and conducting sensitivity analysis are shown in Table 2. For each individual case of change in the value of

the coefficient *c* (%) the country belongs to Class 1 (C1 - countries with favourable EPI indexes) or Class 2 (C2 - countries with non-favourable EPI indexes).

Table 2 *TOPSIS-Sort results with sensitivity analysis*

Countries	*c=10%*		*c=20%*		*c=30%*		*c=40%*		*c=50%*		*c=60%*		*c=70%*		*c=80%*		*c=90%*	
	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
Albania		✓		✓		✓		✓		✓		✓		✓	✓		✓	
B&H		✓		✓		✓		✓		✓		✓		✓		✓	✓	
Bulgaria		✓		✓		✓		✓		✓		✓	✓		✓		✓	
Croatia		✓		✓		✓	✓		✓		✓		✓		✓		✓	
Greece		✓		✓	✓		✓		✓		✓		✓		✓		✓	
Montenegro		✓		✓		✓		✓		✓		✓		✓		✓	✓	
N. Macedonia		✓		✓		✓		✓		✓		✓		✓	✓		✓	
Romania		✓		✓		✓		✓		✓	✓		✓		✓		✓	
Serbia		✓		✓		✓		✓		✓		✓	✓		✓		✓	
Slovenia		✓		✓	✓		✓		✓		✓		✓		✓		✓	

The results of the research showed that, in the case of strict definition of Class 1 (c = 10% and c = 20%), no country has been characterized by a sufficiently high level of environmental performance that would classify them in the Class 1. Only when the value of c = 30% is adopted, Class 1 is formed, to which Greece and Slovenia belong. This leads to the conclusion that these two countries have the most satisfactory values of environmental performance indicators compared to other countries analysed.

With the lowering of the criteria for the formation of Class 1, an increasing number of countries are joining it. Thus, in the cases of c = 40% and c = 50% in Class 1, Croatia has been additionally classified. Considering the results, it can also be seen that at c = 70% a significantly larger number of countries are assigned to Class 1 countries. However, this case is extreme, and cannot be taken as a reliable criterion.

CONCLUSION

This paper analyses the data on the Environmental Performance Index (EPI) according to the latest available Report on EPI values for 2020. The TOPSIS-Sort method was used in order to classify the Balkan countries in the class of favourable and the class of non-favourable in relation to their EPI index values. Consequently, the applicability of this method on the considered data set has been proven.

It has been determined that countries with a strict definition of Class 1 cannot be classified as favourable related to the EPI index, i.e. those with better environmental performance. According to the conducted sensitivity analysis within this study, the countries that were firstly classified into Class 1 are Greece and Slovenia, and those that were lastly classified in Class 1 are B&H and Montenegro. This shows that Greece and Slovenia are the Balkan countries that have the best environmental performance in the observed sample of 10

countries, while B&H and Montenegro are countries with a very low level of environmental performance.

With the exception of Slovenia and Greece, which are ranked 18th and 25th in the EPI methodology's ranking of 180 nations in 2020, the remaining analysed countries cannot boast of environmental protection or high environmental performance. On this basis, it can be concluded that the majority of Balkan Peninsula countries need to engage much more effort in order to improve environmental conditions.

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