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THE IMPACT OF SENSITIVITY ANALYSIS ON THE EVALUATION OF THE LOGISTICS PERFORMANCE INDEX

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Abstract: *The logistics performance index (LPI) represents an important indicator of the state of logistics and its development in countries. The LPI is directly linked to the level of economic system development, and as such provides an adequate basis for the improvement of economy, through logistics and trade. The aim of this paper is to determine the impact of sensitivity analysis on the evaluation and ranking of the LPI in the Balkan countries, according to the report of the World Bank. Sensitivity analysis implies the change of the importance of six criteria based on which the LPI ranking is done. The multi-criteria decision-making model (MCDM), which consists of CRITIC and MARCOS methods for determining the LPI rank in the Balkan countries, was previously used. Criteria weights are simulated through 36 scenarios, whereby the weights of the observed criteria change in the range of 15% - 90%. The final results show that criteria values play very important role in the ranking of the Balkan countries, when it comes to the LPI.*

Key words: *The Logistics Performance Index, sensitivity analysis, ranking, MCDM model, criteria weights, The World Bank.*

JEL classification: C6, E0

1. INTRODUCTION

The Logistics Performance Index was developed by the World Bank in order to rank logistics performance on a global level. In other words, the LPI can be defined as an index of logistics quality that takes into account six different factors. The aim of ranking countries based on the logistics performance index is to determine the state and the possibility of identifying various challenges and their overcoming in the field of logistics and trade. The LPI consists of a set of qualitative and quantitative measures that play a key role in creating a logistics profile of all countries. The LPI measures supply chain performance within a country, and offers two different perspectives, i.e. international and domestic LPI.

The World Bank uses six key dimensions to determine countries' performance and to demonstrate overall logistics performance: efficiency of customs clearance process, infrastructure quality, international shipments - ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments and deliver shipments within scheduled or expected delivery times (timeliness). The first ranking was carried out by the World Bank in 2007, the second in 2010, and from then on, the same was done every two years.

This report represents valuable information, given that logistics is recognized worldwide as a potential area for the development of the entire economy and the economy of a country.

The aim of this paper is to determine the impact of changes in the importance of factors, based on which the LPI ranking is performed, on the final results. As an example, it was considered a total of ten countries, i.e. the entire area of the Balkans. It was applied an integrated MCDM model (Ulutaş and Karaköy, 2019; Isik et al., 2020), which together with the DEA model (Marti et al., 2017; Melo et al., 2020) represents a frequent LPI evaluation technique.

2. APPLIED METHODS

2.1. Criteria Importance Through Intercriteria Correlation - CRITIC method

The CRITIC method consists of the following steps (Diakoulaki et al., 1995, pp. 764-765; Mitrović-Simić et al., 2020, pp. 5-6):

Step 1. Formation of an initial matrix

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} i = 1,2,\dots,m;\ j = 1,2,\dots,n \tag{1}$$

where (x_{ij}) represents the characteristics of the *i* alternative in relation to the *j* criterion.

Step 2. Normalization of the initial matrix depending on the type of criteria:

$$r_{ij} = \frac{x_{ij} - \min\limits_i x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}} \quad ako\ j \in B \rightarrow \max \tag{2}$$

$$r_{ij} = \frac{x_{ij} - \max\limits_i x_{ij}}{\min\limits_i x_{ij} - \max\limits_i x_{ij}} \quad ako\ j \in C \rightarrow \min \tag{3}$$

Step 3. Determination of the symmetric linear correlation matrix r_{ij}

$$= \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - \left(\sum x_i\right)^2} \cdot \sqrt{n\sum y_i^2 - \left(\sum y_i\right)^2}} \tag{4}$$

Step 4. Calculation of the standard deviation (σ) and calculation of the sum of the 1-r*ij* matrix.

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \tag{5}$$

where *n* represents the total number of data in the sample, and $\bar{x}$ is the mean value of the data in the sample.

$$\sum_{j=1}^{n}\left(1 - r_{ij}\right) \tag{6}$$

Step 5. Determination of the amount of information in relation to each criterion: $C_j = \sigma \sum_{j'=1}^{n} 1 - r_{ij}$ (7)

Step 6. Calculation of criterion weights:

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (8)$$

2.2. Measurement and Ranking of Alternatives according to Compromise Solution – MARCOS method

This section presents the algorithm of the MARCOS method, which is based on defining the relationship between alternatives and reference values (ideal and anti-ideal alternatives). Based on the defined relationships, the utility functions of the alternatives are determined and a compromise ranking is made in relation to ideal and anti-ideal solutions. Decision preferences are defined based on utility functions. Utility functions represent the position of an alternative in relation to an ideal and anti-ideal solution. The best alternative is the one that is closest to the ideal and at the same time furthest from the anti-ideal reference point. The MARCOS method is implemented through the following steps (Stević et al., 2020, pp. 4-5; Bouraima et al., 2021, pp. 23-25; Stević and Brković, 2020, pp. 3-5):

Step 1: Formation of an initial decision matrix. Multi-criteria models imply defining a set of criteria and alternatives.

Step 2: Formation of an extended initial matrix. In this step, the initial matrix is extended by defining an ideal (AI) and anti-ideal (AAI) solution.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \dots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{22} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{array} \quad (9)$$

The anti-ideal solution (AAI) represents the worst alternative, while the ideal solution (AI) represents the alternative with the best characteristics. Depending on the nature of the criteria, AAI and AI are defined by applying the following:

$$AAI = \min_j x_{ij} \quad if \ \ j \in B \quad and \quad \max_j x_{ij} \quad if \ \ j \in C \quad (10)$$

$$AI = \max_j x_{ij} \quad if \ \ j \in B \quad and \quad \min_j x_{ij} \quad if \ \ j \in C \quad (11)$$

where B represents the group of benefit criteria, while C represents the group of cost criteria.

Step 3: Normalization of the extended initial matrix (*X*). The elements of the normalized matrix $N = \left[n_{ij} \right]_{m \times n}$ are obtained by applying the following:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad if \ \ j \in C \quad (12)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad if \ \ j \in B \tag{13}$$

where the elements x_{ij} and x_{ai} represent the elements of the matrix *X*.

Step 4: Determination of the weighted matrix $V = \left[v_{ij} \right]_{m \times n}$. The weighted matrix *V* is obtained by multiplying the normalized matrix *N* with the weighting coefficients of the criterion w_j.

$$v_{ij} = n_{ij} \times w_j \tag{14}$$

Step 5: Calculation of the degree of utility of alternatives K_i. By applying Equations (15) and (16), the degree of utility of the alternative is calculated in relation to the anti-ideal and ideal solution.

$$K_i^- = \frac{S_i}{S_{aai}} \tag{15}$$

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{16}$$

where (i=1,2,..,m) represents the sum of the elements of the weighted matrix *V*.

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{17}$$

Step 6: Determination of the utility function of alternatives $f(K_i)$. The utility function represents the compromise of the observed alternative in relation to the ideal and anti-ideal solution. The utility function of alternatives is defined by the following equation:

$$f\left(K_i\right) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1 - f\left(K_i^-\right)}{f\left(K_i^-\right)}}; \tag{18}$$

where $f\left(K_i^-\right)$ represents the utility function in relation to the anti-ideal solution, while $f\left(K_i^+\right)$ represents the utility function in relation to the ideal solution. The utility functions in relation to the ideal and anti-ideal solution are determined by applying the following equation:

$$f\left(K_i^-\right) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{19}$$

$$f\left(K_i^+\right) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{20}$$

Step 7: Ranking the alternatives

3. EVALUATION OF LPI USING A MCDM MODEL

This section of the paper presents a comparison of the results of the logistics performance index for the Balkan countries from 2007 to 2018: Greece, Albania, Bulgaria, Serbia, Croatia, Slovenia, Montenegro, Romania, Bosnia and Herzegovina and North Macedonia. In addition, it is presented an overview of the GDP (gross domestic product) per capita of the Balkan countries in order to determine the correlation with the ranks according to the logistics performance index. The development of a country is measured by gross domestic product per capita, where GDP is divided by the number of inhabitants. Figure 1 shows the GDP per capita of the Balkan countries for 2020 in dollars.

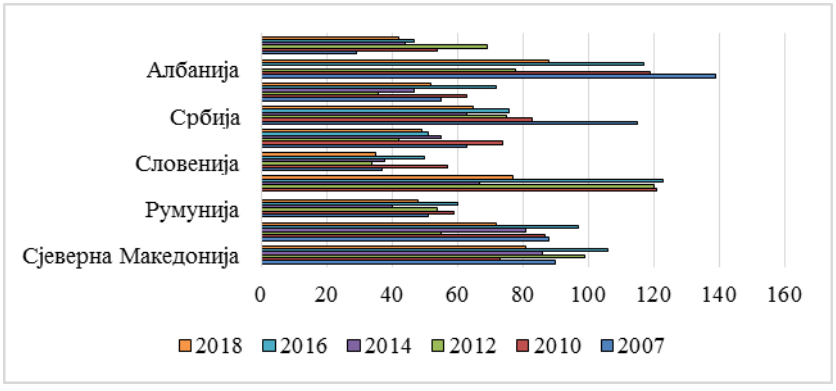
Figure 1. Gross domestic product per capita of the Balkan countries for 2020

Source: GDP per capita (current US$) | Data (worldbank.org)

The ranking of countries by GDP per capita is as follows: Slovenia, Greece, Croatia, Romania, Bulgaria, Montenegro, Serbia, Bosnia and Herzegovina, North Macedonia and Albania. Based on this, it can be seen that the Balkan countries that are in the European Union are economically more developed, which can affect the LPI ranking.

Figure 2 shows the LPI ranking of the Balkan countries from 2007 to 2018. The best-ranked country in the Balkans by GDP per capita was Slovenia, which according to the LPI achieved 3.14 (rank 37) in 2007, and 3.31 (rank 35) in 2018, which is an improvement of 5.41%. The country with the lowest GDP per capita was Albania, which achieved 2.08 (rank 139) on the LPI list in 2007, and 2.66 (rank 88) in 2018, which is an improvement of 27.88%. Greece experienced a decrease of 4.76%, i.e. in 2007 it achieved 3.36 (rank 29), and 3.2 (rank 42) in 2018. North Macedonia experienced progress on the LPI list by 11.11% because it achieved 2.43 (rank 93) in 2007 and in 2018 it achieved 2.7 (rank 81). All other Balkan countries made progress on the LPI list from 2007 to 2018, Croatia by 14.39%, Bosnia and Herzegovina by 14.23%, Serbia by 24.45%, Montenegro by 20.61%, Romania by 7.22% and Bulgaria by 5.57%. Based on this, it can be seen that countries that had higher GDP per capita had less progress on the LPI list compared to countries with lower GDP. This particularly affected Serbia, Montenegro and Albania, which had significant progress on the LPI list compared to Slovenia and Greece, with the exception of Croatia.

Figure 2. International LPI for the Balkan countries from 2007 to 2018



Source: International_LPI_from_2007_to_2018.xlsx (live.com)

Further in the paper, the results of the applied integrated MCDM model are presented. First, the weights of the criteria were calculated using the objective CRITIC method, and the ranks were determined using the MARCOS method. There were used six criteria: Customs (K_1), infrastructure (K_2), international transport (K_3), logistics services (K_4), tracking and tracing of goods (K_5) and

delivery of shipments within scheduled or expected delivery times (K_6) based on which the LPI is defined. All criteria are of benefit type and should be maximized. Alternatives are the Balkan countries, based on the World Bank report for 2018 (Table 1).

Table 1. Initial decision matrix

	K_1	K_2	K_3	K_4	K_5	K_6		K_1	K_2	K_3	K_4	K_5	K_6
GRC	2.84	3.17	3.3	3.06	3.18	3.66	SVN	3.42	3.26	3.19	3.05	3.27	3.7
ALB	2.35	2.29	2.82	2.56	2.67	3.2	MNE	2.56	2.57	2.68	2.72	2.58	3.33
BGR	2.94	2.76	3.23	2.88	3.02	3.31	ROU	2.58	2.91	3.18	3.07	3.26	3.68
SRB	2.6	2.6	2.97	2.7	2.79	3.33	BIH	2.63	2.42	2.84	2.8	2.89	3.21
HRV	2.98	3.01	2.93	3.1	3.01	3.59	MKD	2.45	2.47	2.84	2.74	2.64	3.03

Source: Author's analysis

After applying the CRITIC method, the following criterion values were obtained: w_1=0.119; w_2=0.166; w_3=0.185; w_4=0.156; w_5=0.168; w_6=0.207. Furthermore, it was applied the algorithm of the MARCOS method, the results of which are shown in Table 2.

Table 2. Results of applying the MARCOS method

	(K_1^-)	(K_1^+)	$f(K_i)$	Rank		(K_1^-)	(K_1^+)	$f(K_i)$	Rank
GRC	1.217	0.953	0.709	2	SVN	1.264	0.989	0.736	**1**
ALB	1.030	0.806	0.600	10	MNE	1.050	0.822	0.612	**8**
BGR	1.172	0.917	0.683	5	ROU	1.190	0.931	0.693	**3**
SRB	1.092	0.855	0.636	6	BIH	1.087	0.851	0.633	**7**
HRV	**1.181**	**0.925**	**0.688**	**4**	**MKD**	**1.041**	**0.814**	**0.606**	**9**

Source: Author's analysis

The best-ranked country is Slovenia, and the worst-ranked is Albania.

4. SENSITIVITY ANALYSIS OF THE RESULTS TO CHANGES IN THE IMPORTANCE OF THE CRITERIA

Furthermore, it is necessary to perform sensitivity analysis, i.e. compare the results when the weights of criteria are changed. Sensitivity analysis is done for greater security during implementation in the real sector. In this part of sensitivity analysis, it was analyzed the impact of changing all criteria. The weights of the criteria were changed in the range of 15-90% starting from the most important criterion. For the Balkan countries, the most important criterion is K_3, followed by criteria K_1, K_6, K_4, K_5, K_2. By applying Equation (21) (Erceg et al., 2019, p. 22), a total of 36 scenarios were formed.

$$W_{n\beta} = (1 - W_{n\alpha}) \frac{W_\beta}{(1 - W_n)} \tag{21}$$

In scenarios S_1-S_6, it was changed the most important criterion K_3, criterion K_1 in scenarios S_7-S_{12}, criterion K_6 in scenarios S_{13}-S_{18}, criterion K_4 in scenarios S_{19}-S_{24}, criterion K_5 in scenarios S_{25}-S_{30} and criterion K_2 in scenarios S_{31}-S_{36}. *Wnβ* represents a new value of a criterion, *Wna* represents a reduced value of a criterion, *Wp* is an original value of an observed criterion and *Wn* represents an original value of a criterion, the value of which has been reduced. All simulated criterion values through the newly formed 36 scenarios are presented in Table 3, and the results of sensitivity analysis in Figure 3.

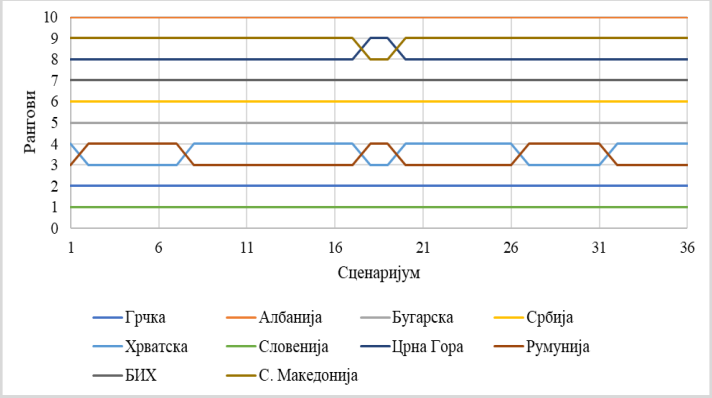
Table 3. Simulated criterion values through newly formed 36 scenarios

	w_1	w_2	w_3	w_4	w_5	w_6		w_1	w_2	w_3	w_4	w_5	w_6
S_1	0.21	0.12	0.18	0.16	0.15	0.18	S_{19}	0.21	0.12	0.22	0.13	0.15	0.17
S_2	0.22	0.13	0.15	0.17	0.15	0.18	S_{20}	0.21	0.12	0.23	0.11	0.15	0.18
S_3	0.23	0.13	0.12	0.17	0.16	0.19	S_{21}	0.22	0.12	0.24	0.08	0.15	0.18
S_4	0.24	0.13	0.09	0.18	0.17	0.20	S_{22}	0.22	0.13	0.24	0.06	0.16	0.19
S_5	0.24	0.14	0.05	0.19	0.17	0.20	S_{23}	0.23	0.13	0.25	0.04	0.16	0.19
S_6	0.25	0.14	0.02	0.19	0.18	0.21	S_{24}	0.24	0.13	0.25	0.02	0.16	0.20
S_7	0.17	0.12	0.23	0.16	0.15	0.18	S_{25}	0.21	0.12	0.22	0.16	0.12	0.17

S_8	0.14	0.12	0.23	0.17	0.15	0.18	S_{26}	0.21	0.12	0.23	0.16	0.10	0.18
S_9	0.11	0.13	0.24	0.17	0.16	0.19	S_{27}	0.22	0.12	0.23	0.17	0.08	0.18
S_{10}	0.08	0.13	0.25	0.18	0.16	0.20	S_{28}	0.22	0.13	0.24	0.17	0.06	0.19
S_{11}	0.05	0.14	0.26	0.18	0.17	0.20	S_{29}	0.23	0.13	0.24	0.17	0.04	0.19
S_{12}	0.02	0.14	0.27	0.19	0.17	0.21	S_{30}	0.23	0.13	0.25	0.18	0.01	0.19
S_{13}	0.21	0.12	0.22	0.16	0.15	0.14	S_{31}	0.21	0.10	0.22	0.16	0.14	0.17
S_{14}	0.21	0.12	0.23	0.16	0.15	0.12	S_{32}	0.21	0.08	0.23	0.16	0.15	0.18
S_{15}	0.22	0.13	0.24	0.17	0.15	0.09	S_{33}	0.21	0.06	0.23	0.16	0.15	0.18
S_{16}	0.23	0.13	0.24	0.17	0.16	0.07	S_{34}	0.22	0.05	0.23	0.17	0.15	0.18
S_{17}	0.23	0.13	0.25	0.18	0.16	0.04	S_{35}	0.22	0.03	0.24	0.17	0.16	0.19
S_{18}	0.24	0.14	0.26	0.18	0.17	0.02	S_{36}	0.23	0.01	0.24	0.17	0.16	0.19

Source: Author's analysis

Figure 3. Results of sensitivity analysis for the new criterion values



Source: Author's analysis

CONCLUSION

In this paper, it was verified the impact of sensitivity analysis on the ranking of the Balkan countries according to the logistics performance index. The results of sensitivity analysis, with the new values of the criteria for the Balkan countries, based on 36 sets representing new criteria, show that there are certain changes. Slovenia represents the best solution, while Albania represents the worst solution. The changes in the ranking of the countries are as follows: Romania, which is in third place in the initial scenario, falls to the fourth position in a large number of scenarios when the value of the criteria is changed. Croatia exchanges its place with Romania, while the same is the case with the eighth-ranked alternative (Montenegro) and the ninth-ranked alternative (North Macedonia), which exchange their positions in the seventeenth and eighteenth scenario. Based on the calculation, it can be concluded that there is an impact of the criterion value on the ranking of the logistics performance index, and this significant parameter should be included when creating the World Bank report.

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SUMMARY

The check of impact of sensitivity analysis on ranking of the Balkan countries based on the LPI is performed in this paper. The LPI is developed by the World Bank in order to perform the ranking of logistics performance on a global level. In other words, the LPI can be defined as logistics quality index, which takes into consideration six different factors. The aim of ranking countries based on logistics performance index is determining the state and the possibility of identifying different challenges and their overcoming in the area of logistics and trade. The LPI consists of a set of qualitative and quantitative measures, which play a key role in creating a logistics profile of all the countries. Sensitivity analysis results, at new criteria values for the Balkan countries based on 36 sets, which represent new criteria, show that there are certain changes. Based on the performed calculation, it can be concluded that there is the impact of criteria values on the ranking of LPI and in producing the report of the World Bank, this important parameter should also be included.