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A MULTI-CRITERIA APPROACH TO THE COMPARATIVE ANALYSIS OF THE GLOBAL INNOVATION INDEX ON THE EXAMPLE OF THE WESTERN BALKAN COUNTRIES

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Original Article

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ABSTRACT

Innovation is crucial for the competitiveness of countries in the global market. Countries oriented to progress must invest in innovative activities. Using the example of the Western Balkan countries, this study investigated their innovative competitiveness. The indicators of the Global Innovation Index (GII) were used for the years 2019, 2020, and 2021. A multi-criteria approach was based on the innovative SMART approach. The weights of the criteria were determined using the CRITIC (criteria importance through intercriteria correlation) method, while the CRADIS (compromise ranking of alternatives from distance to ideal solution) method ranked the Western Balkan countries according to their innovative characteristics. The results showed that Montenegro had the best innovation indicators, followed by Serbia, while Albania had the worst indicators. This research showed an innovative approach of using four normalizations, and the advantages of these normalizations were used to contribute to stabilization in multi-criteria decision-making.

Keywords: *informal labour, informal work, shadow economy, labour, macroeconomics, developing economies, globalisation.*

1. INTRODUCTION

Nowadays, there is an increasing emphasis on the concepts of technology, research and development, competition, customer satisfaction, efficiency, and innovation (Aytekin, et al., 2022). Innovation contributes the most to achieving competitive advantage (Chen, et al., 2018). Innovation is an idea, practice, or object that is perceived as a novelty by an individual (Rogers, 2003). Any new idea, practice, or product that one wants to adopt and apply to improve performance can be understood as an innovation (Hazen, et al, 2012). The development of innovation improves the quality of life of citizens (Pašalić, et al., 2020), and the production and provision of services.

Innovation is a driving force behind economic growth in both national and regional economies. It promotes economic growth, increases wages, extend the product life cycle, makes technology more accessible, improves living standards, and implements new organizational structures (Aytekin, et al., 2022). When discussing innovation, it should not be equated with invention, because innovation is a complex process that adds value to a specific product or service. The role that innovation plays

for companies and countries is increasing. Their application in companies has reduced the lifespan of products and services (Nußholz, 2018). Kovačević, et al., (2021) stated that innovation aims to improve production and business capacities, create new jobs, transfer technology and knowledge, and improve the country's competitiveness in the global market.

To achieve competitive advantages, it is necessary to invest in innovation. Yu, et al. (2021) highlighted that innovation is an indicator of national competitiveness, and it is also related to the economic growth of each country. To achieve higher economic growth, it is necessary to invest in innovation and promote innovation activities. Mašić, et al., (2018) pointed out that innovation improves market efficiency. Investing in innovation activities leads to an increase in the productivity of that country (Carayannis & Grigoroudis, 2016), in addition to an increase in the Gross National Income (GDP) of a country (Comes, et al., 2018).

The increasing crises that have shaken the economic system in recent years, first the financial crisis, then the national debt crisis, then the migration crisis (Kiseľáková, et al., 2019), the COVID-19 pandemic crisis, and the war in Ukraine have shown that innovation must be sustained to survive on the market and to be more competitive at the global level. To follow the innovation capabilities in countries, the Global Innovation Index (GII) is used. The GII reveals the comprehensive innovation effect of countries, helping developing economies to keep pace with technologies (Oturakci, 2022).

The main aim of this study is to examine the innovative level of the Western Balkan countries. The study was conducted based on data obtained for 2019, 2020, and 2021. The comparison of these data was done using the method of multi-criteria analysis (MCDA). An innovative method of ranking alternatives, using four different types of normalization, was taken. Application of the normalization approach was used in the TRUST (multi-normalization multi-distance assessment) method. This method was used by Torkayesh and Devci (2021) in the example of selecting stations for changing batteries in electric scooters.

In this study, the same normalizations were used, but a different methodology for applying those normalizations was conducted. This was applied to other methods, namely: CRITIC (criteria importance through intercriteria correlation) and CRADIS (compromise ranking of alternatives from distance to ideal solution). Based on all of the above, this study has the following objectives:

- To determine the innovative competitiveness of the Western Balkan countries through the GII,
- To innovate the use of four different normalizations in MCDA methods,
- To compare the values of innovation in the observed period

By realizing these objectives, the scientific contribution of this work is achieved. This paper is divided into six sections. In the first section, an introduction is given about the importance of GII, and the objectives of this study are stated. The second section presents the background of the study and an overview of the GII. The third section elaborates on the research methodology and the steps of the MCDA methods. In the fourth section, the results of the research are presented, and the dependence of the ranking on the used criteria determined through sensitivity analysis is shown. The fifth section discusses the obtained research results and compares them with previous research. The sixth section highlights the results of the study and the limitations of the research and provides directions for future research.

2. RESEARCH BACKGROUND

The GII is an index for measuring a country's innovative competitiveness (Huarng and Yu, 2022). This index is generally accepted as a basis for analyzing the innovation competence of countries (Yu, et al., 2021). The GII consists of seven indicators related to innovation inputs and outputs.

Innovation inputs include the following indicators: Institutions (IS), Human Capital and Research (HCR), Infrastructure (IR), Market Sophistication (MS), and Business Sophistication (BS), while innovation outputs include the following indicators: Knowledge and technologies (KT) and Creativity (CR). In this study, the indicators of innovation were collectively observed.

GII indices have been used in various ways in previous studies. Mihaela and Ţiţan (2014) examined the relationships between the human development index, the GII, the education index, and the unemployment rate. The results showed that there is a close correlation between these indicators. Al-Sudairi and Haj Bakry (2014) used GII to investigate the situation in Saudi Arabia with the aim of future knowledge development. Based on this research, they provided recommendations for knowledge development in Saudi Arabia.

Sohn et al. (2016) created a model based on GII indicators using a structural equation model. Their results showed that business sophistication and infrastructure have the strongest direct and indirect effects on creative outputs. Crespo and Crespo (2016) applied qualitative comparative analysis using a fuzzy set and observed two sub-samples of countries (high and low income). The results showed that none of the conditions are necessary for predicting high innovation performance. Jankowska, et al. (2017) applied cluster analysis to GII data. In addition, they carried out a detailed analysis of two countries (Poland and Bulgaria), which aimed to check why these countries failed in sustaining innovations.

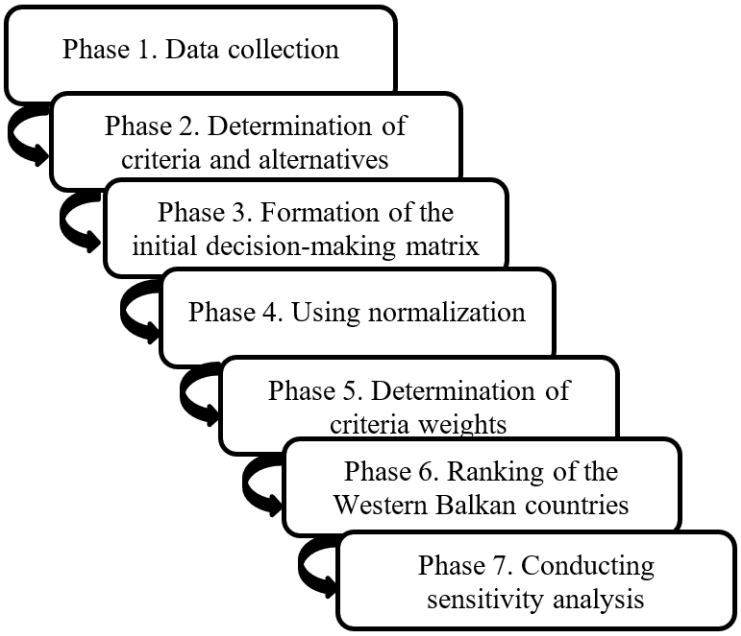
Sener and Delican (2019) examined the relationship between competitiveness, innovation, and foreign trade. They used data from 2007 to 2017 and examined this relationship in a sample of 57 countries. Pence, et al. (2019) used data from the 2016 GII report. When performing the analysis, they used 27 features that they processed through an artificial neural network. The results confirmed that the fitting structure is good enough to determine the approximate results of the countries. Samoilikova, (2020) examined the European and global rankings for innovative development and focused her research on Ukraine. She observed indicators from 2009 to 2019 through correlation and regression analysis. Stojanovic and Ateljevic (2011) investigated how the transition to the innovative model of strategic public sector management in Bosnia and Herzegovina affects its efficiency and effectiveness.

Yu et al. (2021) took data for the period from 2016 to 2020 and used a fuzzy set to identify a common causal combination in each year, which could be used for GII interpretation. Oturakci (2022) observed the relationship between input and output indicators and analyzed it with canonical correlation analysis. In addition, he used a t-test to examine whether the explanatory factors correspond to the country's income levels. Huarng and Yu (2022) used a fuzzy set with qualitative comparative analysis and structural qualitative association on data for 2020. Based on that analysis, a new classification of countries was given based on empirical results.

3. METHODOLOGY

The methodology implemented in this study consists of the stages presented in figure 1.

Figure 1. Methodology of research.



Source: Authors of the research.

This study was conducted to examine the state of innovation in Western Balkan countries. To examine the degree of innovation, the GII was used. The GII project was initiated by Professor Dutt during his tenure at INSEAD (Institut Européen d'Administration des Affaires) in 2007 (Iqbal, 2011). The goal of this project was to determine methods and metrics for researching innovative activities in the world and fourteen GII reports have been issued so far.

For this study, the GII reports from 2019, 2020, and 2021 were used. On that occasion, indicators for innovation inputs and outputs were taken into account, and selected countries were observed using seven criteria. In these reports, the total number of observed countries was from 129 in the 2019 GII report to 132 in the 2021 GII report. From the Western Balkan countries, data were available for: Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, and Serbia, so these countries were taken as alternatives.

After the reports for the last three years were taken and the criteria and alternatives were selected, the initial decision-making matrix was formed. This matrix is the basis for the implementation of all MCDA methods (Puška et al. 2021a). Based on the collected data, three initial decision-making matrices were formed for each observed year. Furthermore, for each of the observed years, a ranking list was determined based on a mutual analysis of the innovation competencies of the Western Balkan countries. In addition, cumulative innovation for the selected years was observed.

The next stage was to conduct normalization. Normalization is the first step in all MCDA methods (Puška, et al. 2018). The goal of normalization is to obtain uniform data on which MCDA operations can be performed. In this case, the goal of all criteria is to make the value as high as possible, so normalization was used for benefit criteria. When implementing the TRUST method, from which the used normalizations were taken, four normalizations were applied, namely: normalization type-1 (simple linear normalization), normalization type-2 (vector normalization), normalization type-3 (complex linear normalization), and normalization type- 4 (logarithmic normalization). In addition to these normalizations, there are several other types in practice, but these normalizations

are mostly used in practice.
After the initial decision matrix was normalized, the next step for each method was to aggravate that decision matrix. To carry out this procedure, it is necessary to determine the weights of the criteria. The weights of the criteria can be determined in two ways: subjective assessment by the decision maker and objective assessment (Nedeljković, et al., 2021). In this research, the CRITIC method was used to determine the objective weight of the criteria. The ranking of alternatives was done using the CRADIS method.
After determining the ranking of the alternatives for the GII reports from 2019, 2020, and 2021, a summary rating of innovations for all three years was formed. This is done in such a way that after the individual normalizations were carried out, the average normalization was calculated and the normalization value was formed together for all years following with a sensitivity analysis. The task of this analysis was to examine how the weight values affect the ranking of the alternatives. When determining the weights of the criteria, the approach implemented by Mešić, et al. (2022) was used.

4. METHODS

The CRITIC method was developed by Diakoulaki et al. (1995). This method used four normalizations. Based on this, the following steps were conducted:
Step 1. Formation of the initial decision matrix (Puška, et al., 2018). This decision matrix was formed based on selected criteria and alternatives. The formation was done by entering the values of the alternatives for the observed criteria in the matrix. In this study, a matrix with five rows (alternatives) and seven columns (criteria) was formed.
Step 2. Normalization of the initial decision matrix. In this step, four normalizations were calculated that are used in the CRADIS method. These normalizations are (Torkayesh and Devci, 2021):

$$\text{type-1 normalization: } n_{ij}^{1} = \frac{x_{ij}}{\max_j x_j}, \tag{1}$$

$$\text{type-2 normalization: } n_{ij}^{2} = \frac{x_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{2}$$

$$\text{type-3 normalization: } n_{ij}^{3} = \frac{(x_{ij} - \min_j x_j)}{(\max_j x_j - \min_j x_j)} \tag{3}$$

$$\text{type-4 normalization: } n_{ij}^{4} = \frac{\log(x_{ij})}{\log(\prod_{i=1}^{m} x_{ij})} \tag{4}$$

where: $\max_j x_j$ – maximum value of the criterion, $\min_j x_j$ – minimum value of the criteria, $\sum_{i=1}^{m} X_{ij}$ – sum of all criteria values, $\prod_{i=1}^{m} x_{ij}$ – product of all the values in the criterion
The normalization value was formed based on the following expression:

$$n_{ij} = 0{,}25 \cdot n_{ij}^{1} + 0{,}25 \cdot n_{ij}^{2} + 0{,}25 \cdot n_{ij}^{3} + 0{,}25 \cdot n_{ij}^{4} \tag{5}$$

Applying this expression, all normalizations were given the same importance in forming the final normalization.
Step 3. Determining the amount of information.

$$C_j = \sigma \sum_{k=1}^{m} (1 - r_{jk}) \tag{6}$$

In this step, it was necessary to calculate the value of the standard deviation (σ) according to the criteria, and to calculate the linear correlation matrix (r) for the criteria.
Step 4. Calculation of final criteria weights.

$$w_j = \frac{c_j}{\sum_{j=1}^{m} c_j} \tag{7}$$

After the criteria weights were calculated, it was necessary to rank the alternatives. The ranking of alternatives was done using the CRADIS method. This method was developed by Puška et al. (2022). As with the CRITIC method, a method correction was performed and four normalizations were used here. The CRADIS method has the following steps:

Step 1. Formation of the decision matrix. The same decision matrix was used as in the CRITIC method.

Step 2. Normalization of the decision matrix. This step was performed in the same way as in the CRITIC method, and the normalization value was determined (n_{ij})

Step 3. Aggravation of the normalized decision matrix. This step was performed by multiplying the values of the normalized decision matrix with the appropriate weights.

$$v_{ij} = n_{ij} \cdot w_j \tag{8}$$

Step 4. Determination of ideal and anti-ideal solutions. The ideal solution represents the greatest value v_{ij} and the anti-ideal solution represents the smallest value v_{ij} in the aggravated decision-making matrix.

$$t_i = \max v_{ij} \tag{9}$$

$$t_{ai} = \min v_{ij} \tag{10}$$

Step 5. Calculation of deviations from ideal and anti-ideal solutions. In this step, the deviation of individual values from the aggravated decision-making matrix was calculated in relation to the ideal and anti-ideal solution. The alternative must be as close as possible to the ideal solution and as far as possible from the anti-ideal solution so that its result is as good as possible.

$$d^+ = t_i - v_{ij} \tag{11}$$

$$d^- = v_{ij} - t_{ai} \tag{12}$$

Step 6. Calculation of the deviation of individual alternatives from ideal and anti-ideal solutions. In this step, the value of the deviation of the alternatives from the ideal and anti-ideal solution was added.

$$s_i^+ = \sum_{j=1}^{n} d^+ \tag{13}$$

$$s_i^- = \sum_{j=1}^{n} d^- \tag{14}$$

Step 7. Calculation of the utility function for each alternative in relation to the deviations from the optimal alternatives. In this step, optimal alternatives were first calculated. These alternatives were formed in such a way that where s_0^+ is the optimal alternative that has the smallest distance from the ideal solution, while s_0^- is the optimal alternative that has the greatest distance from the anti-ideal solution.

$$K_i^+ = \frac{s_0^+}{s_i^+} \tag{15}$$

$$K_i^- = \frac{s_0^-}{s_i^-} \tag{16}$$

Step 8. Ranking of alternatives. The final ranking was obtained by looking for the average deviation of the alternatives from the degree of utility.

$$Q_i = \frac{K_i^+ + K_i^+}{2} \tag{17}$$

5. RESULTS

The first step in calculating the mutual innovativeness of the Western Balkan countries was the formation of the initial decision-making matrix. In this case, three decision matrices were formed for each observed GII report (Table 1).

Table 1. Initial decision matrix.

2019	IS (C1)	HCR (C2)	IR (C3)	MS (C4)	BS (C5)	KT (C6)	CR (C7)
Albania (A1)	65.8	22.7	46.2	53.4	24.0	12.2	24.4
Bosnia and Herzegovina (A2)	58.9	42.0	35.3	49.3	26.5	21.8	19.0
Montenegro (A3)	68.9	33.0	48.8	44.4	32.2	18.5	41.4
North Macedonia (A4)	69.7	26.4	44.9	57.1	30.5	21.6	28.1
Serbia (A5)	68.7	32.4	49.9	39.6	31.9	26.7	27.2
2020	C1	C2	C3	C4	C5	C6	C7
Albania (A1)	66.0	20.3	40.9	46.8	24.1	9.7	19.5
Bosnia and Herzegovina (A2)	59.3	35.0	36.8	50.1	18.7	21.2	14.8
Montenegro (A3)	69.6	33.5	46.0	48.2	23.6	19.6	33.6
North Macedonia (A4)	58.9	29.1	46.4	59.7	25.4	23.0	18.9
Serbia (A5)	69.4	31.7	48.6	41.6	25.8	30.0	20.5
2021	C1	C2	C3	C4	C5	C6	C7
Albania (A1)	64.9	22.7	43.0	44.1	25.0	12.0	20.3
Bosnia and Herzegovina (A2)	59.5	31.4	45.7	49.3	18.8	20.7	15.9
Montenegro (A3)	69.6	32.7	43.2	50.9	25.3	17.1	35.9
North Macedonia (A4)	69.9	30.2	46.9	63.7	25.4	22.7	19.5
Serbia (A5)	69.3	32.3	48.7	48.4	25.5	29.1	21.4

Source: Global forum for intellectual property, data processed by the authors.

Legend: Institutions (IS), Human Capital and Research (HCR), Infrastructure (IR), Market Sophistication (MS), and Business Sophistication (BS), while innovation outputs include the following indicators: Knowledge and technologies (KT) and Creativity (CR)

After the initial decision-making matrix for all years of the observed reports was formed, the method of obtaining the ranking of the Western Balkan countries about the values of the criteria from the GII is explained based on the example of 2019.

The first step was performing normalization (Table 2). Four normalizations were used in this study. Each of these normalizations has its characteristics. Observing the results obtained by applying different normalizations, these characteristics can be identified. When performing type-1 normalization, the values have a weight of one and the highest average value (mean = 0.8267) of all data in about other types of normalization. This normalization tried to align the data values with the maximum value of the criteria. Application of type-2 normalization showed that the average

value of all data is (mean = 0.4406), which is almost half less than the value of type-1 normalization. This normalization calculated the data around the average value and the deviation from this average value found using the standard deviation (SD = 0.0779) is less than with normalization type-1. The results using type-3 normalization showed that the values range between the minimum and maximum values, with the minimum value taking the value zero (0), while the maximum value taking the value one (1). This normalization, therefore, has the largest deviation from the average value for all data (SD = 0.3734) compared to other normalizations. Using type-4 normalization resulted that the average value (mean = 0.2) being the same for all criteria. Based on this, it can be concluded that the normalized values deviate equally from this average value, which is shown by the indicator of standard deviation (SD = 0.0111). With this normalization, the highest conformity of all data was achieved. By using only some of the normalizations, their characteristics would be appreciated. Therefore, the use of all these normalizations seems justified when ranking the alternatives.

Table 2. Normalization of the initial decision matrix.

Type-1	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.9440	0.5405	0.9259	0.9352	0.7453	0.4569	0.5894
A2	0.8451	1.0000	0.7074	0.8634	0.8230	0.8165	0.4589
A3	0.9885	0.7857	0.9780	0.7776	1.0000	0.6929	1.0000
A4	1.0000	0.6286	0.8998	1.0000	0.9472	0.8090	0.6787
A5	0.9857	0.7714	1.0000	0.6935	0.9907	1.0000	0.6570
Type-2	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.4424	0.3174	0.4559	0.4858	0.3676	0.2634	0.3765
A2	0.3960	0.5873	0.3484	0.4485	0.4059	0.4706	0.2932
A3	0.4632	0.4614	0.4816	0.4039	0.4932	0.3994	0.6388
A4	0.4686	0.3691	0.4431	0.5195	0.4671	0.4663	0.4336
A5	0.4619	0.4530	0.4924	0.3603	0.4886	0.5764	0.4197
Type-3	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.6389	0.0000	0.7466	0.7886	0.0000	0.0000	0.2411
A2	0.0000	1.0000	0.0000	0.5543	0.3049	0.6621	0.0000
A3	0.9259	0.5337	0.9247	0.2743	1.0000	0.4345	1.0000
A4	1.0000	0.1917	0.6575	1.0000	0.7927	0.6483	0.4063
A5	0.9074	0.5026	1.0000	0.0000	0.9634	1.0000	0.3661
Type-4	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.1997	0.1825	0.2017	0.2051	0.1891	0.1684	0.1936
A2	0.1944	0.2185	0.1876	0.2010	0.1950	0.2074	0.1784
A3	0.2019	0.2044	0.2046	0.1956	0.2066	0.1964	0.2256
A4	0.2024	0.1913	0.2002	0.2086	0.2033	0.2068	0.2022
A5	0.2017	0.2033	0.2058	0.1897	0.2060	0.2211	0.2002
Total	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.5562	0.2601	0.5825	0.6037	0.3255	0.2222	0.3501
A2	0.3589	0.7014	0.3108	0.5168	0.4322	0.5391	0.2326
A3	0.6449	0.4963	0.6472	0.4129	0.6749	0.4308	0.7161
A4	0.6678	0.3452	0.5502	0.6820	0.6026	0.5326	0.4302
A5	0.6392	0.4826	0.6746	0.3109	0.6622	0.6994	0.4107

Source: Author's calculation.

After the normalization of the data, it was necessary to calculate the weight value of the criteria to rank the alternatives. Therefore, it was necessary to apply the steps of the CRITIC method. The first two steps were performed by calculating the normalization. Then the amount of information was calculated (expression 6) and the final weights were calculated (expression 7). The weights for the years 2020 and 2021 were calculated in the same way (table 3). Based on the results obtained, criterion C4 (w = 0.2032) received the highest weight for the year 2019, while criterion C1 (w = 0.0933) received the lowest weight. With the data for 2020, criterion C4 (w = 0.1740) received the highest weight, while criterion C3 (w = 0.0896) received the lowest weight. For the data for 2021, criterion C7 (w = 0.2196) received the most weight, while criterion C1 (w = 0.0946) received the least weight. The differences in the weights of the criteria are present because the CRITIC method gives more weight to those criteria that have a greater dispersion in the data because one of the elements for calculating the value of the CRITIC method is the standard deviation. If a certain criterion is not connected to another, then that also contributes to greater weight. To avoid this in the sensitivity analysis, the aggregate weight for the criteria was calculated.

Table 3. Value of criteria weights.

2019	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
$C_j = \sigma \sum_{k=1}^{m} (1 - r_{jk})$	0.5613	1.2067	0.7023	1.2232	0.5892	0.9303	0.8060
w	0.0933	0.2005	0.1167	0.2032	0.0979	0.1546	0.1339
2020	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
$C_j = \sigma \sum_{k=1}^{m} (1 - r_{jk})$	0.7822	0.9132	0.5017	0.9741	0.6607	0.9093	0.8564
w	0.1397	0.1631	0.0896	0.1740	0.1180	0.1624	0.1530
2021	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
$C_j = \sigma \sum_{k=1}^{m} (1 - r_{jk})$	0.4420	0.6136	0.5564	0.6116	0.6932	0.7304	1.0263
w	0.0946	0.1313	0.1191	0.1309	0.1483	0.1563	0.2196

Source: Author's calculation.

After the weights of the criteria were calculated, the steps of the CRADIS method were applied to rank the Western Balkan countries according to the innovation index. Since the normalized decision-making matrix was formed and the weights of the criteria were determined, the next step was to make the normalized decision-making matrix more aggravated (table 4). Table 4 shows all the aggravated decision matrices for individual reports.

Table 4. Aggravated normalized decision matrix.

2019	C1	C2	C3	C4	C5	C6	C7
A1	0.0519	0.0521	0.0680	0.1227	0.0319	0.0343	0.0469
A2	0.0335	0.1406	0.0363	0.1050	0.0423	0.0833	0.0312
A3	0.0601	0.0995	0.0755	0.0839	0.0661	0.0666	0.0959
A4	0.0623	0.0692	0.0642	0.1386	0.0590	0.0823	0.0576
A5	0.0596	0.0968	0.0787	0.0632	0.0648	0.1081	0.0550
2020	C1	C2	C3	C4	C5	C6	C7
A1	0.0792	0.0431	0.0404	0.0736	0.0694	0.0275	0.0542
A2	0.0522	0.1112	0.0296	0.0853	0.0373	0.0778	0.0350
A3	0.0938	0.1043	0.0537	0.0786	0.0664	0.0709	0.1111
A4	0.0506	0.0839	0.0548	0.1196	0.0771	0.0856	0.0517
A5	0.0930	0.0959	0.0605	0.0550	0.0795	0.1156	0.0582
	C1	C2	C3	C4	C5	C6	C7
A1	0.0492	0.0399	0.0447	0.0414	0.0954	0.0326	0.0750
A2	0.0342	0.0821	0.0613	0.0544	0.0471	0.0728	0.0507
A3	0.0623	0.0884	0.0459	0.0584	0.0977	0.0562	0.1599
A4	0.0631	0.0763	0.0687	0.0904	0.0985	0.0819	0.0706
A5	0.0615	0.0864	0.0798	0.0522	0.0992	0.1111	0.0810

Source: Author's calculation.

The next step in implementing the CRADIS method was finding ideal and anti-ideal solutions. The ideal solution is the maximum value of all alternatives for all criteria, while the anti-ideal solution is the minimum value of all alternatives for all criteria (expressions 9 and 10). When the determinations are ideal and anti-ideal solutions, the deviation of individual data from these values was calculated (expressions 11 and 12). Since deviations from ideal and anti-ideal solutions were observed, two decision matrices were formed to represent these deviations. After the matrices of deviations from ideal and anti-ideal solutions were formed, the sum of these deviations was calculated for all alternatives and optimal alternatives (expressions 13 and 14). The next step was to calculate the utility functions about the optimal alternatives (expressions 15 and 16), then the value of the CRADIS method (expression 17) was calculated and the alternatives were ranked (table 5).
The results of the CRADIS method show that Montenegro has the best innovation index among the Western Balkan countries for 2019, followed by North Macedonia and Serbia. Albania, which took the last place, has the worst indicators. Looking at the indicators in the report for 2020, Montenegro had the best results. However, unlike the previous report, it was followed by Serbia and then North Macedonia. The last place was occupied by Albania. The ranking results according to the report for 2021 show that Serbia had the best indicators in terms of innovation index, followed by Montenegro and North Macedonia. As with the previous analyses, Albania also had the worst indicators according to this report.

Table 5. Ranking list of alternatives.

2019	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	Rank
Albania (A1)	0.5766	0.5101	0.1897	0.4017	0.4559	5
Bosnia and Herzegovina (A2)	0.5122	0.5742	0.2541	0.5381	0.5562	4
Montenegro (A3)	0.4368	0.6734	0.3295	0.6979	0.6856	1
North Macedonia (A4)	0.4512	0.6519	0.3151	0.6673	0.6596	2
Serbia (A5)	0.4582	0.6419	0.3081	0.6525	0.6472	3
2020	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	**Rank**
Albania (A1)	0.4496	0.3242	0.1951	0.3910	0.3576	5
Bosnia and Herzegovina (A2)	0.4085	0.3568	0.2362	0.4734	0.4151	4
Montenegro (A3)	0.2583	0.5643	0.3864	0.7745	0.6694	1
North Macedonia (A4)	0.3137	0.4647	0.3310	0.6635	0.5641	3
Serbia (A5)	0.2792	0.5220	0.3655	0.7325	0.6273	2
2021	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	**Rank**
Albania (A1)	0.7410	0.5766	0.1501	0.3235	0.4501	5
Bosnia and Herzegovina (A2)	0.7166	0.5962	0.1745	0.3762	0.4862	4
Montenegro (A3)	0.5503	0.7764	0.3408	0.7347	0.7555	2
North Macedonia (A4)	0.5697	0.7500	0.3214	0.6929	0.7214	3
Serbia (A5)	0.5479	0.7797	0.3431	0.7398	0.7598	1

Source: Author's calculation.

By observing the results for the selected years (table 5), it can be concluded that the ranking order of the Western Balkan countries changed. This is especially evident in the first three places. To perform a sensitivity analysis and to obtain aggregate data, an analysis was performed for all observed years. When applying normalization, all three years were taken into account in normalization, but the maximum values and minimum values were taken from all three years, so individual normalization was done on that basis. In this way, the data from the report was taken into account for all years, not only for individual years. After that, individual normalizations were calculated for the observed periods and the average normalization was calculated for all three selected years (table 6). Based on that normalization, the weight values for all criteria were calculated. These results show that the highest value was given to criterion C6 (w = 0.1962), while the lowest value was given to criterion C5 (w = 0.0700). These weights are needed to form scenarios for sensitivity analysis.

In addition to calculating the weights, CRADIS method values were also calculated for aggregate indicators for the selected years. These results show that Montenegro has the best overall results, followed by Serbia (table 6). In this case, too, Albania had the worst overall results in terms of the innovation index.

Before performing the sensitivity analysis, it was necessary to create a summary decision matrix for all years. This was done by performing normalization for the observed years using the highest value of the criterion in all years. Then the average value of the normalized decision-making matrices was calculated, and the aggregate normalized decision-making matrix was formed. A sensitivity analysis was applied to this decision matrix (Table 6).

Table 6. Summary analysis for 2019, 2020 and 2021.

Normalized decision matrix							
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.5140	0.2437	0.4801	0.4010	0.4166	0.1874	0.3030
A2	0.3363	0.5465	0.3787	0.4254	0.3230	0.4486	0.2055
A3	0.6206	0.4814	0.5452	0.3966	0.4988	0.3744	0.6154
A4	0.5308	0.3857	0.5469	0.6014	0.5009	0.4801	0.3184
A5	0.6140	0.4616	0.6210	0.3195	0.5204	0.6413	0.3358
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
$C_j = \sigma \sum_{k=1}^{m} (1 - r_{jk})$	0.4246	0.6914	0.3124	0.7060	0.2678	0.7503	0.6714
w	0.1110	0.1808	0.0817	0.1846	0.0700	0.1962	0.1756
Aggravated decision matrix							
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	0.0571	0.0441	0.0392	0.0740	0.0292	0.0368	0.0532
A2	0.0373	0.0988	0.0309	0.0785	0.0226	0.0880	0.0361
A3	0.0689	0.0870	0.0445	0.0732	0.0349	0.0735	0.1081
A4	0.0589	0.0697	0.0447	0.1110	0.0351	0.0942	0.0559
A5	0.0682	0.0835	0.0507	0.0590	0.0364	0.1258	0.0590
	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	**Rank**	
A1	0.5474	0.5135	0.1752	0.3969	0.4552	5	
A2	0.4886	0.5753	0.2340	0.5301	0.5527	4	
A3	0.3908	0.7193	0.3318	0.7516	0.7354	1	
A4	0.4114	0.6833	0.3112	0.7049	0.6941	3	
A5	0.3983	0.7057	0.3243	0.7345	0.7201	2	

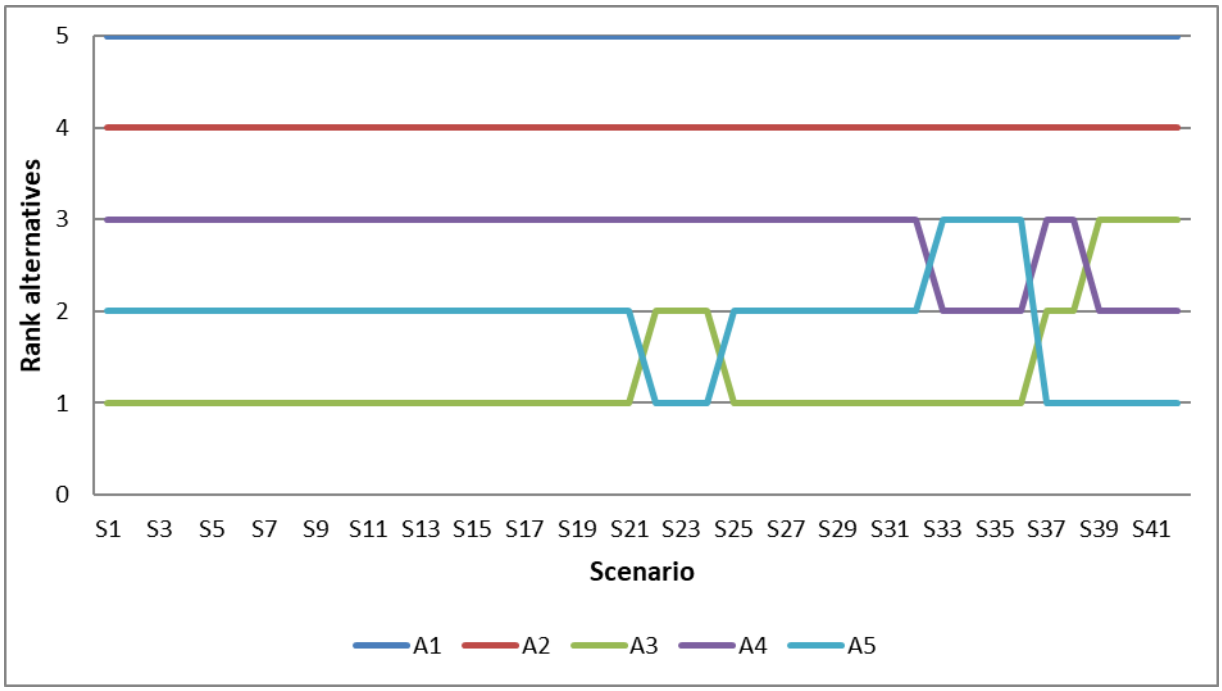
Source: Author's calculation.

After the aggregate normalization was formed and the criteria weights for the aggregate data were determined, a sensitivity analysis was performed. When conducting the sensitivity analysis, we used the approach introduced by Mešić, et al. (2022). With this approach, the scenarios were formed as follows. Each criterion was reduced proportionally by 15%, so in the first scenario, the weight value for criterion C1 was reduced by 15% and is 85% of the initial value. The other criteria were then increased in proportion to that decrease in the first criterion. In the second scenario, the first criterion decreased by another 15% and amounted to 70% of the initial value, while the other weights were proportionally increased for that decrease. In this way, the value of the first criterion was reduced by up to 10%. The same procedure was carried out for each criterion and in this way, 42 scenarios were formed.

The results of the sensitivity analysis show that the 28 scenarios retained the same order as the overall results (Figure 2). In this way, the obtained findings were confirmed. For scenarios 22 and 24, the ranking order was changed compared to the original order in such a way that Serbia showed the best results (Figure 2). These results showed that Serbia has worse indicators compared to Montenegro in terms of the market sophistication criterion, so with a reduction in the weight of this criterion, Serbia achieved a better result. This is also the case for scenarios 32 to 42 scenarios. In scenarios 33 to 36, North Macedonia achieved better results than Serbia, because Serbia had better indicators in the knowledge and technology criteria compared to North Macedonia, so with the reduction of the weight of this criterion, there was a change in the ranking order. Scenarios 37

to 42 showed that Serbia showed better indicators than Montenegro, while from scenarios 39 to 42 North Macedonia showed better results than Montenegro. The sensitivity analysis showed that the ranking of the countries Bosnia and Herzegovina and Albania did not change, regardless of which scenario was applied.

Figure 2. Results of the sensitivity analysis.



Source: Authors of the research.

6. DISCUSSION

To improve its global competitiveness every country must innovate and invest in innovation (Aytekin, et al., 2022). Competitiveness is measured using the GII (Yu, et al., 2021). The GII report is issued annually. To examine innovative activities in the Western Balkan countries, data from 2019, 2020, and 2021 were used. The reports covered 129 countries in total for 2019 and 132 countries in total for 2021. Five countries of the Western Balkan are covered in this report. When measuring innovation in GII, seven main indicators are used, which were selected as criteria in this study.

Due to the existence of seven criteria and five alternatives, this research problem was solved using the MCDA method. The first step of any MCDA method is to perform data normalization (Puška, et al., 2021b). Each normalization has its characteristics and performs data processing differently. To take advantage of different data normalizations, the methodology of using four normalizations developed by Torkayesh and Devci (2021) was applied. In this study, that methodology was incorporated into the CRITIC and CRADIS methods. In this way, an innovative approach to the use of normalization in MCDA methods is offered. The weights of the criteria were determined using the CRITIC method, while the ranking of Western Balkan countries was done using the CRADIS method.

The application of different types of normalization showed how it transforms data into uniform data whose value ranges from zero (0) to one (1). Application of type-1 normalization placed the data in such a way that they have the highest average value. Their value was closest to the maximum value. Type-2 normalization grouped the data around a certain mean. In this way, neither value received a maximum value (one) nor a minimum value (zero). The situation is similar to normalization type-4, which grouped all values around the value 0.20. With this normalization, the smallest value

is the deviation from the average value. Type-3 normalization, however, places the criterion values between the maximum and minimum possible values by normalization. The data obtained by this normalization showed the greatest dispersion in values.

By using all these normalizations together, their characteristics were used equally. This is because all normalizations participated equally in the formation of the final normalization value. The values obtained in this way were close to the mean value of normalization (0.50) and the dispersion between the data was not too pronounced, and not too small either. This is because different normalizations and their characteristics are used. For the decision maker to be sure of the ranking order, they should use this approach. This is because normalization has a great impact on the ranking of alternatives (Trung, 2022). The more normalization the decision maker uses, the decision will be more reliable, and the more different possibilities will be available.

The results of weights for indicators according to different reports showed that due to oscillations in the data, the value of these weights changed. Changes in the weights also change the significance of the criterion for which the weight is changed. If the value is higher, its importance is higher, and vice versa. Thus, the greatest importance for the data in 2019 was for criterion C4, in 2020 was for criterion C4, and in 2021 was for criterion C7.

When ranking the Western Balkan countries according to the data from the individual report, Montenegro achieved the best indicators for the years 2019 and 2020, while Serbia showed the best indicators for the year 2021. Serbia improved the market sophistication indicator the most (C4), while other indicators remained at similar values. There was also an increase in these characteristics in Montenegro, but the indicator of creativity decreased. However, when looking at the official GII reports, Montenegro is ranked better than Serbia even for 2021. This is due to the use of weights because in the report each criterion has the same weight and therefore affects the ranking equally.

To examine the influence of weights on the ranking of alternatives, a sensitivity analysis was used. A specific feature of this study is the fact that several reports were used, so it was necessary to consolidate these data. An innovative methodology was applied to unify the data, where three initial decision-making matrices were observed together. Data for normalization were taken from all three matrices. Based on these normalized data, the weights used in the sensitivity analysis were calculated.

The performed sensitivity analysis shows from aggregate data that Montenegro has the best results, followed by Serbia and North Macedonia. Albania showed the worst results according to all conducted analyses. Montenegro showed sensitivity to the change in weights for the market sophistication and creativity criteria. In these scenarios, Serbia was ranked better. Using the example of the Western Balkan countries, it has been shown how individual countries can be compared with each other using the MCDA methods.

7. CONCLUSION

The purpose of this study was to examine the level of innovativeness of the Western Balkan countries and to compare them. The results of the analysis showed that according to the indicators from the GII report, Montenegro has been the most competitive in terms of innovation. In addition, these results showed that Albania is the least competitive of the selected countries of the Western Balkans, followed by Bosnia and Herzegovina. All these countries, to be as competitive as possible on the global market, must invest in strengthening innovative activities.

Limitations regarding the conducted study are expressed in the criteria used. However, these criteria are part of the GII report, and each of these criteria has its sub-criteria. There are no sub-criteria values in the report, so only key criteria were selected. In addition, the number of observed countries is one of the limitations of this study. The GII reports covered these five countries. In future studies, it is necessary to include more countries in the research. As possibility is to analyze Europe as a sample of observation and examine whether countries outside the European Union give importance to innovation to the same extent as countries in the European Union. In addition, in future research, it is necessary to compare and contrast developing countries with developed countries.

This study aimed to offer an innovative normalization method, where four different normalizations were used. Therefore, it is necessary to understand this study as a conceptual one that elaborates on new methods and procedures. The study showed that the use of four different normalizations makes sense in MCDA methods, this approach should be used in future research.

REFERENCES

Al-Sudairi, M., & Haj Bakry, S. (2014). Knowledge issues in the global innovation index: Assessment of the state of Saudi Arabia versus countries with distinct development. *Innovation*, 16(2), 176-183. https://doi.org/10.1080/14479338.2014.11081980

Aytekin, A., Ecer, F., Korucuk, S., & Karamaşa, Ç. (2022). Global innovation efficiency assessment of EU member and candidate countries via DEA-EATWIOS multi-criteria methodology. *Technology in Society*, 68, 101896. https://doi.org/10.1016/j.techsoc.2022.101896

Brem, A., Viardot, E., & Nylund, P. A. (2021). Implications of the Coronavirus (COVID-19) outbreak for innovation: Which technologies will improve our lives? *Technological Forecasting and Social Change*, 163, 120451. https://doi.org/10.1016/j.techfore.2020.120451

Carayannis, E. G., & Grigoroudis, E. (2016). Using multiobjective mathematical programming to link national competitiveness, productivity, and innovation. *Annals of Operations Research*, 247(2), 635-655. https://doi.org/10.1007/s10479-015-1873-x

Chen, J., Yin, X., & Mei, L. (2018). Holistic Innovation: An Emerging Innovation Paradigm. *International Journal of Innovation Studies*, 2(1), 1-13. https://doi.org/10.1016/j.ijis.2018.02.001

Comes, C-A., Bunduchi, E., Vasile, V., & Stefan, D. (2018). The Impact of Foreign Direct Investments and Remittances on Economic Growth: A Case Study in Central and Eastern Europe. *Sustainability*, 10(1), 238. https://doi.org/10.3390/su10010238

Crespo, N. F., & Crespo, C. F. (2016). Global innovation index: Moving beyond the absolute value of ranking with a fuzzy-set analysis. *Journal of Business Research*, 69(11), 5265-5271. https://doi.org/10.1016/j.jbusres.2016.04.123

Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The critic method. *Computers & Operations Research*, 22(7), 763-770. https://doi.org/10.1016/0305-0548(94)00059-h

Hazen, B. T., Overstreet, R. E., & Cegielski, C. G. (2012). Supply chain innovation diffusion: going beyond adoption. *The International Journal of Logistics Management*, 23(1), 119-134. https://doi.org/10.1108/09574091211226957

Huarng, K.-H., & Yu, T. H.-K. (2022). Analysis of Global Innovation Index by structural qualitative association. *Technological Forecasting and Social Change*, 182, 121850. https://doi.org/10.1016/j.techfore.2022.121850

Iqbal, A. (2011). Creativity and innovation in Saudi Arabia: An overview. *Innovation*, 13(3), 376-390. https://doi.org/10.5172/impp.2011.13.3.376

Jankowska, B., Matysek-Jędrych, A., Mroczek-Dąbrowska, K. (2017). Efficiency of national innovation systems: Poland and Bulgaria in the context of the Global Innovation Index. *Comparative Economic Research*, 20(3), 77-94. https://doi.org/10.1515/cer-2017-0021

Kiseľáková, D., Šofranková, B., Gombá, M., & Čabinová, V., (2019). Onuferová E. Competitiveness and Its Impact on Sustainability, Business Environment, and Human Development of EU (28) Countries in terms of Global Multi-Criteria Indices. *Sustainability*, 11(12), 3365. https://doi.org/10.3390/su11123365

Kovačević, S., Rebić, M., & Kurušić, D. (2021). The impact of the inflow of foreign direct investments on the economic development of Serbia. *ECONOMICS - Innovative and Economics Research Journal*, 9(2), 123-142. https://doi.org/10.2478/eoik-2021-0022

Mašić, B., Nešić, S., & Vladušić, L. (2018). Challenges in creating transformative growth for companies in digital economy. *ECONOMICS - Innovative and Economics Research Journal,* 6(2), 37-48. https://doi.org/10.2478/eoik-2018-0024

Mešić, A., Miškić, S., Stević, Ž., Mastilo, Z. (2022). Hybrid MCDM solutions for evaluation of the logistics performance index of the Western Balkan countries. *ECONOMICS - Innovative and Economics Research Journal*, 10(1), 13-34. https://doi.org/10.2478/eoik-2022-0004

Mihaela, M., & Ţiţan, E. (2014). Education and Innovation in the Context of Economies Globalization. *Procedia Economics and Finance*, 15, 1042-1046. https://doi.org/10.1016/s2212-5671(14)00667-4

Nedeljković, M., Puška, A., Doljanica, S., Virijević Jovanović, S., Brzaković, P., Stević, Ž., Marinkovic, D. (2021). Evaluation of rapeseed varieties using novel integrated fuzzy PIPRECIA – Fuzzy MABAC model. *PLoS ONE*, 16(2), e0246857.b https://doi.org/10.1371/journal.pone.0246857

Nußholz, J. L. K. (2018). A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops. *Journal of Cleaner Production*, 197, 185–194. https://doi.org/10.1016/j.jclepro.2018.06.112

Oturakci, M. (2022). Comprehensive analysis of the global innovation index: statistical and strategic approach. *Technology Analysis & Strategic Management*. Article in press. https://doi.org/10.1080/09537325.2021.1980209

Pašalić, S., Mastilo, Z., Đurić, A., & Marković, D. (2020). Demographic trends and the educational system of the Republic of Srpska. *ECONOMICS - Innovative and Economics Research Journal*, 8(1), 93-113. https://doi.org/10.2478/eoik-2020-0007

Pence, I., Kalkan, A., & Cesmeli, M. S. (2019). Estimation of the Country Ranking Scores on the Global Innovation Index 2016 Using the Artificial Neural Network Method. *International Journal of Innovation and Technology Management*, 16(4), 1940007. https://doi.org/10.1142/s0219877019400078

Puška, A., Beganović, A., & Šadić, S. (2018). Model for investment decision-making by applying the multi-criteria analysis method. *Serbian Journal of Management*, 13(1), 7-28. https://doi.org/10.5937/sjm13-12436

Puška, A., Nedeljković, M., Zolfani, S. H., & Pamučar, D. (2021). Application of Interval Fuzzy Logic in Selecting a Sustainable Supplier on the Example of Agricultural Production. *Symmetry*, 13(5), 774. https://doi.org/10.3390/sym13050774

Puška, A., Pamucar, D., Stojanović, I., Cavallaro, F., Kaklauskas, A., Mardani, A. (2021b). Examination of the Sustainable Rural Tourism Potential of the Brčko District of Bosnia and Herzegovina Using a Fuzzy Approach Based on Group Decision Making. *Sustainability*, 13(2), 583. https://doi.org/10.3390/su13020583

Puška, A., Stević, Ž. & Pamučar, D. (2022). Evaluation and selection of healthcare waste incinerators using extended sustainability criteria and multi-criteria analysis methods. *Environment, Development and Sustainability*, 24(9), 11195-11225. https://doi.org/10.1007/s10668-021-01902-2

Radukić, S., Mastilo, Z., Kostic, Z., Vladusic, L., (2019). Measuring of The Goods and Labor Markets Efficiency: Comparative Study of Western Balkan Countries. *Montenegrin Journal of Economics, Economic Laboratory for Transition Research (ELIT)*, 15(2), 95-109. https://doi.org/10.14254/1800-5845/2019.15-2.8

Rogers, E. M. (2003). Diffusion of Innovations. New York, Free Press.

Samoilikova, A. (2020). Financial Policy of Innovation Development Providing: The Impact Formalization. *Financial Markets, Institutions and Risks*, 4(2), 5-15. https://doi.org/10.21272/fmir.4(2).5-15.2020

Sener, S., & Delican, D. (2019). The causal relationship between innovation, competitiveness and foreign trade in developed and developing countries. *Procedia Computer Science*, 158, 533-540. https://doi.org/10.1016/j.procs.2019.09.085

Sohn, S. Y., Kim, D. H., & Jeon, S. Y. (2015). Re-evaluation of global innovation index based on a structural equation model. *Technology Analysis & Strategic Management*, 28(4), 492-505. https://doi.org/10.1080/09537325.2015.1104412

Stojanović, I., & Ateljević, J. (2011). Innovation in The Public Sector The Way Forward For An Effective Reform Of Public Sector Management In Bosnia And Herzegovina, In Conference Proceedings "Economic Development And Entrepreneurship In Transition Economies", Banja Luka, 184.

Trung, D.D. (2022). Development of data normalization methods for multi-criteria decision making: applying for MARCOS method. *Manufacturing Review*, 9, 22. https://doi.org/10.1051/mfreview/2022019

Yu, T. H.-K., Huarng, K.-H., & Huang, D.-H. (2021). Causal complexity analysis of the Global Innovation Index. *Journal of Business Research*, 137, 39-45. https://doi.org/10.1016/j.jbusres.2021.08.013