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***PSI-AROMAN Assessment of the WB6 Countries Innovation Performance***

THE 6TH VIRTUAL INTERNATIONAL CONFERENCE
PATH TO A KNOWLEDGE SOCIETY-MANAGING RISKS AND INNOVATION, OCTOBER 21-22, 2024, MATHEMATICAL INSTITUTE SANU.

Miomir Stanković, PhD
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# Darjan Karabašević

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# Proceedings of the
# 6th Virtual International Conference
# Path to a Knowledge Society-
# Managing Risks and Innovation


Editors:
Stanković, M. and Nikolić, V.



Publishers:
Complex System Research Center, Niš, Serbia
Mathematical Institute of the Serbian Academy
of Sciences and Arts, Belgrade, Serbia

October 21-22, 2024

Editors
Stanković, M.
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# PaKSoM 2024

## 6th Virtual International Conference
## Path to a Knowledge Society-Managing Risks and Innovation

Proceedings

Publishers
Complex System Research Centre, Niš, Serbia
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Serbia, Niš, October 21-22, 2024

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Technical Editor:
Dr. Lazar Z. Velimirović

Published by:
Complex System Research Centre, Niš, Serbia, and
Mathematical Institute of the Serbian Academy of Sciences and Arts

Printed by:
Copy House, Niš, Serbia

Number of copies printed: 100
The publishing year: 2025

Printing of this edition has been financially supported by
The Ministry of Science, Technological Development and Innovation of the Republic of Serbia

ISBN 978-86-82602-04-0

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

005.94(082)
005.591.6(082)
007:004(082)

VIRTUAL international conference Path to a Knowledge Society-Managing Risks and Innovation (6 ; 2024 ; Niš)
Proceedings / 6th Virtual international conference Path to a Knowledge Society-Managing Risks and Innovation PaKSoM 2023, Serbia, Niš, October 21-22, 2024 ; [organizer Mathematical Institute of the Serbian academy of sciences and arts] ; [co-organizers Complex System Research Centre] ; editors Stanković, M. [Miomir], Nikolić, V. [Vesna]. - Niš : Complex System Research Centre : Mathematical Institute of SASA, 2025 (Niš : Copy house). - 346 str. : ilustr. ; 25 cm

Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-82602-04-0 (CSRC)

а) Знање -- Менаџмент -- Зборници б) Предузећа -- Пословање -- Иновације -- Зборници в) Информациона технологија -- Зборници

COBISS.SR-ID 161737737

# PaKSoM 2024

## $6^{th}$ Virtual International Conference
## Path to a Knowledge Society-Managing Risks and Innovation

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**PaKSoM 2024**
DOI: https://doi.org/10.5281/zenodo.14693341

*Original Scientific Article*

# PSI-AROMAN Assessment of the WB6 Countries Innovation Performance

Gabrijela Popović[1], Vuk Mirčetić[2], Darjan Karabašević[3,4]

[1,2,3]Faculty of Applied Management, Economics and Finance, Belgrade, Serbia
[4]College of Global Business, Korea University, Sejong, Republic of Korea

[1]gabrijela.popovic@mef.edu.rs, [2]vuk.mircetic@mef.edu.rs, [3]darjan.karabasevic@mef.edu.rs

*Abstract*—**This paper will examine the performance of West Balkan countries (WB6) in the research and innovation field (R&I). Their performance is assessed according to 12 main R&I aspects. The procedure is based on the Multiple-Criteria Decision-Making methods. The Preference Selection Index (PSI) was applied to define the weighting coefficients. At the same time, the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) was used to assess the R&I performance of the selected countries. The results revealed Serbia as the best performer in the R&D field in this part of the world.**

**Keywords –** R&D, WB6, PSI, AROMAN.

## I. Introduction

An organization's development and endurance strongly depend on research and innovation (R&I) activities because permanent technological change and limited resources make the environment severely competitive. Managers and governments have a difficult task to find the adequate ways to support these activities because the economic development and growth are under the influence of R&I [1]. Besides, encouraging innovation is the 9$^{th}$ goal of the 2030 Agenda for Sustainable Development [2-4]. Unsurprisingly, the authors have shown significant interest in the topics that deal with the innovation activities conducted within the organizations and countries [5-10]. The European Commission introduced the European Innovation Scoreboard (EIS) to respond to the rising need to measure the degree of innovativeness of a country [11]. Proposed innovation indicators represent metrics that assess innovation achievements in a wider context [12]. The authors have proposed combining the EIS indicators with the Multiple-Criteria Decision-Making (MCDM) techniques to elicit adequate scientific results.

MCDM techniques facilitate decision-making in complex environments characterized by numerous alternatives and conflicting evaluation criteria [13]. Various MCDM approaches have been proposed until now (for example [14-18]), and each has pros and cons. Additionally, different combinations of MCDM methods and models have been proposed for analyzing the R&I performance of selected countries [19-24].

For the need of this research, we assessed Western Balkan′s countries (WB6) using the MCDM model that consists of the Preference Selection Index (PSI) [25] and the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) [26]. The PSI method was used to define the weighting coefficients. The reason for applying this method is that its computation procedure is based on input data that exclude the possibility of obtaining biased weightings. The AROMAN method was applied to the final assessment of the WG6 country's innovation performance. It is a newly introduced method whose potential has yet to be fully observed in different scientific cases, so we decided to base our analysis on it. The assessment was performed regarding 12 main R&I aspects presented in the EIS report for 2024 [27]. To present the conducted research and obtained results, the remainder of the paper is

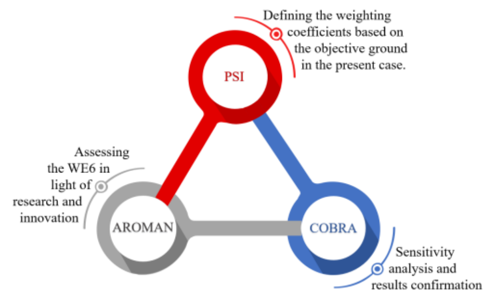


Figure 1. Employed MCDM methods.

organized as follows: Section 2 presents the methodology used; Section 3 involves the case study; and the conclusion is presented at the end of the article.

## II. Methodology

This paper employed three MCDM methods, as presented in Fig.1.

Because the COBRA method is used only for sensitivity analysis, its computation procedure is omitted from the methodology section.

### A. *The PSI Method*

The PSI method [25] defined the weighting coefficients based on the objective ground in the present case. Namely, the PSI method uses the initial data in the weighting coefficients computing, which excludes the possibility of decision-maker interference in the case when the data is quantitative. The positive side of the PSI method is not only the determination of objective weights but also the possibility of ranking the considered alternatives. The whole assessment procedure could be based solely on this method. It revealed the potential to resolve many decision-making problems, which proves the following articles [28-32].

The computation procedure of the PSI method contains the following series of steps.

**Step 1.** Select the evaluation criteria and alternatives.

**Step 2.** Evaluate the alternatives against the selected criteria and construct the primary decision matrix *X*:

$$x = \left[ x_{ij} \right]_{n \times m}, \tag{1}$$

where $x_{ij}$ is the performance ratings of the alternative *i* regarding the criterion *j*, *n* is the number of alternatives, and *m* is the number of criteria.

**Step 3.** Define the normalized decision matrix using the following equations:

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for maximization criteria,} \tag{2}$$

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for minimization criteria.} \tag{3}$$

**Step 4.** Calculate the preference variation value regarding each criterion in the following way:

$$\chi_j = \sum_{i=1}^{m} \left( r_{ij} - \bar{r}_j \right)^2, \tag{4}$$

where $\bar{r}_j$ represents the mean value of normalized ratings of criterion *j* defined as follows:

$$\bar{r}_j = \frac{1}{m} \sum_{i=1}^{m} r_{ij}. \tag{5}$$

**Step 5.** Calculate the deviation in the preference variation value as follows:

$$\Omega_j = 1 - X_j. \tag{6}$$

**Step 6.** Determine the criteria weights $w_j$ using the following equation:

$$w_j = \frac{\Omega}{\sum_{i=1}^{n} \Omega_j}. \tag{7}$$

**Step 7.** Compute the preference selection index of alternatives in the following way:

$$S_i = \sum_{j=1}^{n} r_{ij} w_j. \tag{8}$$

The highest preference selection index value signifies the best option alternative.

### B. *The AROMAN Method*

The AROMAN method [26] is used to assess the WE6 in light of research and innovation. Although it was introduced recently, the authors used it and its extensions in a significant number of research studies. The following articles [33-43] prove this constatation.

The computation procedure of the AROMAN method could be illustrated by the following series of steps.

**Step 1.** Form the initial decision matrix $X$ as in the procedure for the PSI method.

**Step 2.** Normalize the decision matrix. In this case, the normalization procedure involves the linear, the vector normalization, and finally, the aggregated averaged normalization.

Linear normalization is performed in the following way:

$$t_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \quad (9)$$

$$i = 1, 2, \ldots, n, j = 1, 2, \ldots m. \quad (10)$$

Vector normalization is performed as follows:

$$t_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}}, \quad (11)$$

$$i = 1, 2, \ldots, n, \; j = 1, 2, \ldots, m. \quad (12)$$

Aggregated averaged normalization is done to achieve the final normalized values, and it is performed in the following manner:

$$t_{ij}^{norm} = \frac{\beta t_{ij} + (1-\beta) t_{ij}^{*}}{2}, \quad (13)$$

$$i = 1, 2, \ldots, n, \; j = 1, 2, \ldots, m, \quad (14)$$

where $t_{ij}^{norm}$ represents the aggregated averaged normalization, and $\beta$ is the weighting coefficient that varies from 0 1 to and usually is set on 0.5.

**Step 3.** Define the weighted decision matrix. This matrix is defined using (15):

$$\hat{t}_{ij} = w_{ij} \times t_{ij}^{norm}. \quad (15)$$

**Step 4.** Calculate the sum of the normalized weighted values for the cost and the benefit criteria separately as follows:

$$L_i = \sum_{j=1}^{m} \hat{t}_{ij}^{(\min)}, \quad (16)$$

$$i = 1, 2, \ldots, n; \; j = 1, 2, \ldots, m., \quad (17)$$

$$A_i = \sum_{j=1}^{m} \hat{t}_{ij}^{(\max)}, \quad (18)$$

$$i = 1, 2, \ldots, n; \; j = 1, 2, \ldots, m, \quad (19)$$

where $L_i$ stands for cost, and $A_i$ for benefit type of criteria.

**Step 5.** Rank the alternatives. The final ranking of the alternatives is obtained in the following way:

$$R_i = L_i^{\lambda} + A_i^{(1-\lambda)}, \; i = 1, 2, \ldots, n, \quad (20)$$

where $R_i$ represents the value for ranking the alternatives, and $\lambda$ is the coefficient level of the criterion type. If both criterion types are involved in the procedure, $\lambda$ is set to 0.5. The alternatives ranking is performed in descending order.

## III. CASE STUDY

### A. Data

The evaluation is done against the 12 main aspects presented in Table I. The R&I performance of the EU-member countries, neighboring countries and selected global competitors are measured against 12 aspects and 32 indicators. The findings are published annually in the EIS since 2001. For this research, we evaluated the WG6 country's R&I performance using the MCDM model (Table II).

TABLE I. R&D ASPECTS [27].

| Abbr. | Aspect | Optim. |
|---|---|---|
| HR | Human resources | max |
| AS | Attractive research systems | max |
| DI | Digitalization | max |
| FS | Finance and support | max |
| FI | Firm investments | max |
| IT | Use of information technologies | max |
| IN | Innovators | max |
| LI | Linkages | max |
| IA | Intellectual assets | max |
| EI | Employment impacts | max |
| SI | Sales impacts | max |
| ES | Environmental sustainability | max |

TABLE II. WB6[*] [44].

| Abbr. | Country |
|---|---|
| AL | Albania |
| BA | Bosnia and Herzegovina |
| ME | Montenegro |
| MK | North Macedonia |
| RS | Serbia |

The initial decision matrix is based on data retrieved from the European Innovation Scoreboard for 2024 [27], and it is presented in Table III. There was a missing value for the FS – Finance support aspect, which we fulfilled with the data for the previous year [45].The further analysis was based on initial data presented in Table III.

*B. Results*

The weighting coefficients were determined using the PSI method. Table IV presents the obtained results.

TABLE IV. ASPECTS′ WEIGHTING COEFFICIENTS.

| Abbr. | Aspect | $w_j$ |
|---|---|---|
| HR | Human resources | 0.0842 |
| AS | Attractive research systems | 0.0985 |
| DI | Digitalization | 0.0874 |
| FS | Finance and support | 0.0454 |
| FI | Firm investments | 0.0536 |
| IT | Use of information technologies | 0.0967 |
| IN | Innovators | 0.1003 |
| LI | Linkages | 0.0770 |
| IA | Intellectual assets | 0.0771 |
| EI | Employment impacts | 0.0942 |
| SI | Sales impacts | 0.0902 |
| ES | Environmental sustainability | 0.0954 |

The results emphasized the aspect IN – Innovators as the most significant. Surprisingly, the aspect FS – Finance and support has the slightest influence on the R&I performance of the countries.

After defining the weighting coefficients, we used the AROMAN method to perform the final analysis and determine the ranking order of the selected countries regarding their R&I achievements. The procedure is performed using (2)-(8), and the final score and ranking order are shown in Table V.

TABLE V. RESULTS

| Abbr. | Country | $R_i$ | Rank |
|---|---|---|---|
| RS | Serbia | 0.3284 | 1 |
| ME | Montenegro | 0.2505 | 2 |
| MK | North Macedonia | 0.2319 | 3 |
| AL | Albania | 0.1524 | 4 |
| BA | Bosnia and Herzegovina | 0.1439 | 5 |

The final ranking order highlights Serbia as the best innovation performer within the WB6 countries group. Serbia expressed very satisfying

TABLE III. INITIAL DECISION MATRIX [27,45].

| Aspect / Country | HR | AS | DI | FS | FI | IT | IN | LI | IA | EI | SI | ES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % | % | % | % |
| AL | 59.3 | 36.1 | 14.2 | 0.0 | 12.7 | 45.6 | 75.3 | 40.1 | 5.9 | 38 | 47.5 | 66.4 |
| BA | 10.3 | 23.2 | 35.8 | 0.0 | 0.8 | 39.8 | 117.6 | 15 | 14.9 | 50.8 | 29.6 | 89 |
| ME | 34.4 | 49.6 | 54.7 | 12.5 | 23.8 | 69.4 | 170.3 | 73.5 | 8.9 | 100.5 | 20.9 | 52.3 |
| MK | 36 | 79.7 | 37.1 | 14.5 | 42.1 | 30.9 | 63.2 | 49.4 | 21.5 | 31.6 | 59.6 | 87.4 |
| RS | 48.6 | 43.4 | 64.1 | 42.7 | 102.4 | 92 | 135.7 | 77.8 | 21.9 | 71.7 | 64.8 | 31.1 |

[*] Kosovo* is excluded from the assessment because Serbia does not recognize it as an independent state.

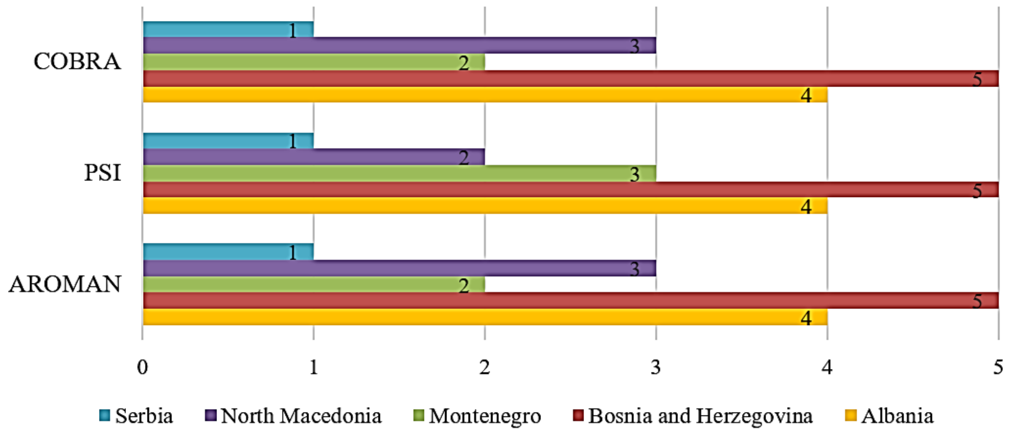


Figure 2. Sensitivity analysis.

parameters regarding all the R&I aspects. Although some performances of Serbia were not so good, overall ranking results put it in first place as the most perspective R&I performer among the WB6 countries group.

### C. *Sensitivity Analysis*

The results obtained with the help of the AROMAN method were compared with those defined by using the PSI and the COBRA methods. The main reason for this was to check the reliability of the defined ranking order. Fig. 2 illustrates the comparison performed.

Although the rankings of the AROMAN and PSI methods differ slightly, the reliability of the proposed MCDM model is proved.

## IV. Conclusion

The goal of this article was to address the possibilities of the MCDM model in evaluating the performance of the WB6 countries in the R&I landscape. The PSI method successfully and objectively determined the weighting coefficients, while the AROMAN method enabled an easy and reliable definition of the country's ranking order. The robustness and reliability of the model are proved using the COBRA and PSI methods.

The results outlined Serbia as a country that has made the best progress regarding R&I, while Bosnia and Herzegovina have the worst performance in the considered field. Fedajev et al.'s article confirms that Serbia is the best performer among WB6 countries observed through the R&I prism [23].

The benefits of the research include the comprehensiveness and ease of use of the proposed MCDM model. The proposed approach enabled the defining of adequate objective weighting coefficients and adequate ranking order, which is in accordance with similar research. The MCDM model could be successfully used to analyze any kind of decision problem, not only issues regarding R&I.

The essential limitation of the presented work is that it is based only on the EIS indicator set. It would be more satisfying if more relevant sources regarding the innovation indicators were used (e.g., the Global Innovation Index report). In that case the same problem would be observed from different perspectives, which would enable us to look at the WB6 countries' R&I achievements from different angles. Nevertheless, enhancing the methodological approach and involving MCDM methods with different methodology backgrounds would be desirable to elicit more objective results.

The proposition for further research includes comparing the WB6 countries with the achievements of the EU-27 countries regarding the R&I. The comparison with developed countries would bring good insight into what fields the WB6 countries should improve to reach the R&I level of developed countries. Furthermore, it would be advisable to incorporate the standpoints of experts, especially considering the aspects against which the R&I performance is measured. The standpoints of the experts could be included in the analysis by employing the subjective MCDM weighting methods, such as some from the PIPRECIA family. Everything said would lead to the creation of a more relevant and robust model that will enable drawing more robust and relevant scientific conclusions that respect the objective as well as the subjective aspects of the decision process.

Finally, it could be concluded that the proposed MCDM model facilitates the assessment process, resulting in quite adequate results. The approach is very understandable, which makes it convenient even for users unfamiliar with the MCDM field. Furthermore, this model could be used to improve the decision-making process in various scientific and business fields.

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