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# Digital Innovation Performance Evaluation of European Union Member and Candidate Countries with IDOCRIW and CRADIS Methods

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**ABSTRACT**

This study evaluates the digital innovation performance of European Union (EU) members and candidate countries by applying a novel integrated multi-criteria decision-making (MCDM) approach. Specifically, the IDOCRIW method is employed to determine objective weights for digital innovation indicators derived from the Global Innovation Index (GII) 2024 report, while the CRADIS method is utilized to assess and rank country performance. The research incorporates indicators directly related to digital innovation, including ICT use, software spending, mobile app creation, GitHub activity, high-tech and ICT exports, mobile application creation, e-participation, and university–industry collaboration. The results highlight significant disparities in digital innovation performance among the analysed countries. Cyprus, Ireland, and the Netherlands emerged as the top performers, whereas Albania, Bosnia and Herzegovina, and Georgia ranked lowest. The integrated model provides a robust and transparent framework for comparative innovation analysis, offering valuable insights for policymakers aiming to enhance digital innovation capacity.

## 1. Introduction

Innovation is the main driver of economic growth and development, increasing the competitiveness of countries; it makes a significant contribution to the economic and social transformation processes of developing countries which deal with economic difficulties in particular [1-2]. There are many definitions in the literature regarding the concept of innovation and its types. In general, innovation types are considered on two main axes: according to their field and according to their degree. In the classification according to their field, product innovation means the introduction of a new product to the market or the major modification of an existing product, while process innovation refers to innovations that reduce costs in production or delivery processes. Organizational innovation is structural innovations made with the aim of reducing management costs, making faster decisions and increasing flexibility. Marketing innovation provides competitive

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advantage by introducing a completely new product, process or way of doing business in the sector. In the classification according to their degree, radical innovation defines radical changes that bring brand new products, processes or business models to the sector [3], while incremental innovation refers to gradual improvements in existing products, processes or ways of doing business [4].

Innovation is the creation of economic value by combining existing or new resources in different ways, as Schumpeter defined it in 1934 as “new combinations” [5]. As [6] state, digital innovation is a transformative process that enables countries at the macro level and organizations at the micro level to develop new products, services, or processes using digital technologies. Digital innovation is the production of this value through digital technologies in short, it is a type of innovation based on data, algorithms, and online platforms. Therefore, although digital innovation shares the goals of classical innovation, it differs from it by making innovation faster and scalable using digital technologies. In this way, digital innovation contributes to the economic growth of businesses and, more broadly, economies [7].

In the literature, studies that jointly examine innovation measurement and Multi-Criteria Decision-Making (MCDM) methods are summarized below. Oralhan and Büyüktürk [4] have studied the innovation performance of 28 EU member, three candidate and five neighboring countries using ten key indicators obtained from the 2018 European Innovation Index. TOPSIS and MOORA have been applied for the evaluation; although the results were similar in both methods, some differences were observed in the rankings. According to both methods, Switzerland, Sweden and Denmark were ranked first, while Ukraine and Romania were ranked lowest. Ecer and Aycin [1] have used various MCDM methods (MEREC, CODAS, MABAC, MARCOS, CoCoSo, WASPAS and MAIRCA) to evaluate the Innovation Performance of G7 countries. As a result of the study, it was revealed that "business sophistication" was the most critical innovation indicator and the USA came first in the overall ranking. Xu et *al.,* [8] measured the sustainable innovation efficiency of 27 EU countries between 2000 and 2017 using DEA. The results show that sustainable innovation efficiency varies significantly across countries. Only eight countries were consistently efficient during this period. Although the efficiency value seems high at 0.7403 for the EU, there are obvious differences among five regions. In addition, the efficiency of the northern and southern regions is consistently above the EU average. In the analysis conducted by Öztaş and Öztaş [9], firstly assigned objective weights to the indicators with the LOPCOW method to evaluate the innovation performance of the G20 countries and then compared the five-year performance of the countries with the MAIRCA method. According to the results of the study, the United States, the United Kingdom, Germany and South Korea are the countries with the most successful innovation performance. Satı [10] have used the Entropy based TOPSIS method to measure the digital innovation performance of SMEs in the EU and candidate countries. As a result, Austria, Denmark and Germany ranked in the top three; Türkiye, Serbia and Croatia ranked in the bottom three.

Despite the growing research interest in digital innovation, literature on digital innovation is still in an infancy stage [7]. According to Xu et *al., [8]*, the European Union has long attached importance to innovation strategies in the process from the Lisbon Strategy to the EU 2020 Strategy and still gives importance today. As Satı [10] emphasizes, digital innovation offers the EU new opportunities to achieve its innovation goals. For the reasons mentioned above, the aim of the study is to measure the digital innovation performance of EU members and candidate countries. The innovation performance of countries within various groups such as EU members, OECD countries, G7 etc. has been addressed in the literature. However, the number of studies on digital innovation performance for these groups is quite limited. Although this paper is similar to the study by Satı [10], it differs in terms of the criteria and methodology employed. The criteria used in this study are the criteria included in Global Innovation Index (GII) 2024 [11] and are directly related to digital innovation indicators. To our knowledge, no prior studies have utilized these digital innovation criteria from the GII. Moreover, the new integrated IDOCRIW-based CRADIS method is used to evaluate the innovation performance of countries within the scope of the study. The reasons for using the CRADIS method include its ability to provide balanced rankings based on distances to ideal and anti-ideal solutions, its effectiveness in handling conflicting criteria, and its flexibility in adapting to various weighting and normalization [12]. The CRADIS method ensures that changes in criteria or alternatives do not affect the ranking results and thus provides a highly stable and consistent framework for MCDM. The proposed model in this study distinguishes the current study from other studies, providing a novel methodological and empirical contribution to the analysis of digital innovation.

This study is structured as follows: Section 2 explains the CRADIS method and provides a summary of the relevant literature. Section 3 describes the methodology of the objective weighting methods, including Entropy, CILOS, and IDOCRIW. Section 4 presents the application of the proposed approach and reports the results obtained. Finally, Section 5 offers the conclusion and provides recommendations for future research.

## 2. CRADIS Method

In decision-making problems where criterion weights are predetermined, different MCDM methods are used to evaluate alternatives. In this study, the CRADIS method, which has been recently introduced to the literature and has very limited application examples, is preferred. The CRADIS method was introduced by Puška et *al.,* [12] and is a utility function-based evaluation approach that considers the distance of alternatives from ideal and anti-ideal solutions. The main purpose of this method is to analyze the distances of each alternative from the best and worst reference points and rank them according to these deviations [13]. The CRADIS method has been applied in various fields in literature. The literature review for this method is presented in Table 1.

**Table 1**
Literature review for CRADIS method

| Author(s) | Method(s) | Research Issue |
|---|---|---|
| [12] | FUCOM (Full Consistency Method), CRADIS | Selection of healthcare waste incinerators |
| [13] | Fuzzy SWARA (Step-Wise Weight Assessment Ratio Analysis), MABAC (Multi attributive Border Approximation Area Comparison), MARCOS, CRADIS | Green supplier selection |
| [14] | Modified Standard Deviation Method, CRADIS | Evaluation of agricultural machinery, tractor selection |
| [15] | PCA-DEA (Principal Component Analysis and Data Envelopment Analysis, IMF-SWARA, CRADIS | Evaluating the impact of foreign direct investments on the sustainability of the economic system |
| [16] | CRITIC (CRiteria Importance Through Intercriteria Correlation), CRADIS | Analysis of the global innovation index of the Western Balkan countries |
| [17] | LOPCOW (LOgarithmic Percentage Change-driven Objective Weighting), CRADIS | Evaluating prosperity performances of G7 countries |
| [18] | SWARA, FUCA (Faire Un Choix Adéquat), CRADIS | Assessing the energy efficiency of smart factories |
| [19] | MAIRCA (Multi-Attributive Ideal-Real Comparative Analysis), MABAC (Multi-Attributive Border Approximation Area Comparison), MARCOS (Measurement Alternatives and Ranking according to Compromise Solution), CRADIS | Optimization of the performance of end milling processes |

**Table 1**
Continued

| Author(s) | Method(s) | Research Issue |
| --- | --- | --- |
| [20] | PSO (Particle Swarm Optimization), GA (Genetic Algorithm), DP (Dynamic Programming), DEA (Differential Evolutionary Algorithm) LOPCOW (Logarithmic Percentage Change-driven Objective Weighting), CRADIS | Selection of appropriate portfolio optimization strategy |
| [21] | DEMATEL (The Decision-Making Trial and Evaluation Laboratory), CRADIS | Evaluating resilient supply chain strategies in health care systems |
| [22] | MEREC (Method based on the Removal Effects of Criteria), CRADIS | Selection of electric cars |
| [23] | Fuzzy LMAW (Logarithm Methodology of Additive Weights), Entropy, fuzzy CRADIS | Selection of the insurance company in agriculture |
| [24] | Entropy, CRADIS | Evaluation of Balkan countries based on the economic freedom index |
| [25] | Fuzzy FUCOM, CCSD (Correlation Coefficient and Standard Deviation), CRADIS | Building and insulation material selection |
| [26] | SPC (Symmetry Point of Criterion), CRADIS, CURLI (Collaborative Unbiased Rank List Integration) | Woodworking machinery selection for small business in Vietnam |
| [27] | LOPCOW, CRADIS | Selection of hydrogen fuel cell logistics path |
| [28] | Fuzzy CRADIS | Evaluating the effect of the COVID-19 pandemic on medical waste disposal |
| [29] | LOPCOW-CRADIS | Project performance analysis of Turkish universities |
| [30] | Weighted CRITIC CRADIS-Copeland | Blockchain service provider selection for data management in the internet of medical things |
| [31] | LBWA (Level Based Weight Assessment) and MEREC, CRADIS | Financial performance evaluation of the firms in the BIST sustainability 25 index |
| [32] | SWARA-MEREC, CRADIS | Evaluating the performance of logistics companies on the Fortune 500 Turkey list |
| [33] | RAWEC (Ranking of Alternatives with Weights of Criterion), SAW, ARAS, MABAC, MARCOS, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje), WASPAS (Weighted Aggregated Sum Product Assessment), CRADIS | Selection of distribution centers |
| [34] | SWARA, CRADIS | Selection of green contractor for solar power plant project |
| [35] | Fuzzy CRADIS | Occupational risk assessment in natural gas pipeline construction |
| [36] | Entropy, CRADIS | Evaluating sustainable energy management strategies in smart factories |
| [37] | Entropy, CRADIS | Examining the role of social media in information sharing during crises. |
| [38] | Grey-CRADIS, WSM (Weighted Sum Model), TOPSIS | Strategic construction company selection |

CRADIS, which reorganizes some of the steps of existing MCDM methods, also has a unique structure and makes an innovative contribution to the field of MCDM [12]. This method is a synthesis of steps inspired by methods such as TOPSIS, MARCOS and ARAS. The CRADIS method consists of seven systematic steps supported by formulas [12].

*Step 1.* The decision matrix is constructed as shown in Equation 1.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad i = 1,2,\ldots,m \quad j = 1,2,\ldots,n \tag{1}$$

*Step 2.* Decision matrix is normalized. While normalizing the decision matrix, Equation (2) for benefit criteria and Equation (3) for cost criteria are used.

$$n_{ij} = \frac{x_{ij}}{x_{jmax}} \tag{2}$$

$$n_{ij} = \frac{x_{jmin}}{x_{ij}} \tag{3}$$

*Step 3.* The normalized decision matrix is transformed into a weighted decision matrix by multiplying it by the weight of each criterion by using Equation (4).

$$v_{ij} = n_{ij} \cdot w_j \tag{4}$$

*Step 4.* Ideal and anti-ideal solutions are determined. The ideal solution is obtained by taking the highest $v_{ij}$ value in the weighted decision matrix and the anti-ideal solution is obtained by taking the lowest $v_{ij}$ value as given in Equation (5) and (6).

$$t_i = max\, v_{ij} \tag{5}$$

$$t_{ai} = min\, v_{ij} \tag{6}$$

*Step 5***.** Deviations from ideal and anti-ideal solutions are calculated using Equations (7) and (8).

$$d^{+} = t_i - v_{ij} \tag{7}$$

$$d^{-} = v_{ij} - t_{ai} \tag{8}$$

*Step 6***.** The grades of deviation of each alternative from the ideal and anti-ideal solutions are found with the help of Equations (9) and (10) respectively.

$$s_i^{+} = \sum_{j=1}^{n} d^{+} \tag{9}$$

$$s_i^{-} = \sum_{j=1}^{n} d^{-} \tag{10}$$

*Step 7.* The utility function for each alternative is calculated for deviations from the optimum alternatives via Equations (11) and (12).

$s_0^{+}$= the optimal alternative with the shortest distance from the ideal solution

$s_0^{-}$= the optimal alternative with the greatest distance from the anti-ideal solution

$$K_i^{+} = \frac{s_0^{+}}{s_i^{+}} \tag{11}$$

$$K_i^{-} = \frac{s_i^{-}}{s_0^{-}} \tag{12}$$

*Step 8.* The final ranking is determined by the average deviation of the utility of the alternatives by using Equation (13). The best alternative is the alternative with the highest $Q_i$ value.

$$Q_i = \frac{K_i^{+} + K_i^{-}}{2} \tag{13}$$

## 3. Objective Weighting Methods

### *3.1. Entropy*

The concept of entropy, which originates from the second law of thermodynamics, was first introduced by Rudolph Clausius in 1865 as a measure of disorder and uncertainty in a system [39]. In 1948, Shannon proposed the entropy method to address uncertain information and missing data. Later, entropy was adopted as a tool to determine the objective weights of criteria in decision-making processes, based on the degree of value dispersion [40]. The entropy method, which is grounded in probability theory and used to evaluate uncertain information, can effectively assign objective weights to each criterion, as the weight reflects the relative importance of that criterion [41]. The steps of the entropy method are outlined below [42].

*Step 1.* Assuming that there are *m* alternatives and *n* criteria, the decision matrix is constructed with $x_{ij}$ values as shown in Equation (14). In this matrix, $x_{ij}$ represents the performance value of alternative *i* with respect to criterion *j.*

$$\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, \quad (i = 1, 2, 3, \dots, m \; and \; j = 1, 2, 3, \dots, n) \tag{14}$$

*Step 2.* Decision matrix is normalized. The elements of the normalized decision matrix ($\bar{x}_{ij}$) are obtained with the help of Equation (15).

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad (i = 1, 2, 3, \dots, m \; and \; j = 1, 2, 3, \dots, n) \tag{15}$$

*Step 3.* Entropy values $(e_j)$ are determined for each criterion by using Equation (16).

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} \bar{x}_{ij} \ln(\bar{x}_{ij}) \tag{16}$$

*Step 4.* The degree of diversification $(d_j)$ is calculated using Equation (17).

$$d_j = 1 - e_j \tag{17}$$

*Step 5.* Objective weight of each criterion is determined via Equation (18).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{18}$$

### *3.2. CILOS*

CILOS (The Criterion Impact Loss) method, first proposed by [43], is used to determine objective weights of criteria. This method assesses the loss of importance (impact) of the remaining criteria when one criterion is considered optimal. The smaller the relative loss in impact caused by a criterion, the greater its assigned weight. Conversely, if the relative loss is significant, the criterion receives a lower weight [44]. Moreover, the CILOS method addresses the issue of underestimating a criterion's weight when the alternative values are close to that criterion [45]. The steps of the CILOS method are as follows [43]:

*Step 1.* Decision matrix is formed as seen in Equation (14).

*Step 2.* Cost (minimization) criteria are transformed into benefit criteria by using Equation 19. Benefit criteria are not changed and all the criteria become benefit (Maximization) criteria

$$r_{ij} = \begin{cases} \dfrac{\min_i(x_{ij})}{x_{ij}} & If \; j \in C \\ x_{ij} & If \; j \in B \end{cases} \tag{19}$$

*Step 3.* Decision matrix is normalized via Equation (20)

$$\bar{x}_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{20}$$

*Step 4.* The maximum values for each criterion are determined as shown in Equation (21)

$$a_j = \operatorname{maks}_j(\bar{x}_{ij}) = a_{k_i j} \tag{21}$$

*Step 5.* Matrix *A* is formed whose diagonal elements consist of the maximum values determined for each criterion as shown in Equation (22). The other elements of the square matrix A are determined by using Equation (23). The element in row *i* of the square matrix is the element in row $k_i$ of the decision matrix, separately for each criterion.

$$A = \left[a_{ij}\right]_{nxn}\ ;\ a_{jj} = a_j \tag{22}$$

$$a_{ij} = a_{k_i j} \tag{23}$$

*Step 6.* Relative Loss Matrix *P* is formed. The elements of the relative impact loss matrix ($P_{ij}$) are calculated with the elements of matrix *A* as shown in Equation (24).

$$P_{ij} = \frac{a_{jj} - a_{ij}}{a_{jj}},\quad P_{ii} = 0,\ \ (i, j = 1, 2, 3, \dots, n) \tag{24}$$

The value $P_{ij}$ represents the relative loss of criterion *j.* if criterion *i.* is selected as the optimal criterion. It shows the relative loss of the criterion.

*Step 7.* Weight System Matrix (*F*) is formed. Elements of this matrix are calculated with the elements of the relative impact loss matrix as shown in Equation (25).

$$F = \begin{bmatrix} -\sum_{i=1}^{m} p_{1i} & p_{12} & \cdots & p_{1m} \\ p_{21} & -\sum_{i=1}^{m} p_{2i} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & -\sum_{i=1}^{m} p_{mi} \end{bmatrix} \tag{25}$$

*Step 8.* Impact Loss Weights of criteria are calculated by solving the linear system equation shown in Equation (26).

$$F.q = 0 \tag{26}$$

Criteria impact loss vector $(q)$ consists of criteria weights $\left(q_j,\ j = 1, 2, 3, \dots, m\right)$ and the linear system equation is solved as shown in Equation (27).

$$q = F^{-1}.B \tag{27}$$

The vector B consists of values very close to zero.

*Step 9.* Weights of the criteria are determined by using Equation (28).

$$w_j = \frac{|q_j|}{\sum_{j=1}^{m} |q_j|} \tag{28}$$

### *3.3. IDOCRIW*

The IDOCRIW (Integrated Determination of Objective CRIteria Weights) method is an objective weighting approach proposed by Zavadskas and Podvezko [43]. It integrates the criteria weights derived from different objective weighting methods, thereby balancing the limitations of each method with the strengths of the others [44]. This integration allows for the combination of the Entropy and CILOS methods, both of which objectively determine criteria weights [43]. In the IDOCRIW method, the weights obtained from the Entropy method $\left(a_j\right)$ and the CILOS method $\left(b_j\right)$ are combined to produce a final comprehensive weight. This final weight is calculated using Equation (29) [46].

$$w_j = \frac{a_j b_j}{\sum_{j=1}^{m} a_j b_j} \tag{29}$$

Weights obtained with IDOCRIW show the variation of the criteria as a feature of the Entropy method. However, the significance of the criteria is reduced by the high loss in the other criterion [46].

## **4. Application of the Proposed Method**

To verify the effectiveness of the proposed model, this paper evaluates digital innovation performance among EU members and candidate countries. The evaluation criteria are selected directly from the Global Innovation Index (GII) 2024, focusing specifically on digital innovation indicators. Moreover, the novel IDOCRIW-based CRADIS method is employed for comprehensive performance assessment. Table 2 includes the criteria included in GII 2024 that are directly related to digital innovation performance [11].

**Table 2**
Digital innovation performance indicators included in the GII

| Indicators | Definition |
|---|---|
| GitHub commits/mn pop. 15–69 | The number of GitHub commits per million population ages 15-69. This measures digital technology development activity in the country. |
| High-tech exports, % total trade | Percentage of high-technology exports in the country's total foreign trade. This rate expresses the export capacity of high-technology products. |
| ICT services exports, % total trade | The export ratio of information and communication technology (ICT) services to the country's total trade. This criterion measures the contribution of ICT services to the economy. |
| Software spending, % GDP | It is the ratio of total expenditures on software to the country's gross domestic product (GDP). It shows the country's investment in the software field. |
| Mobile app creation/bn PPP$ GDP | The number of mobile applications developed per billion dollars of a country's gross domestic product in purchasing power parity (PPP). This criterion shows the level of mobile application development activity relative to the size of the economy. |
| University–industry R&D collaboration† | It measures the level of research and development collaboration between university and industry. It represents innovative partnerships between higher education institutions and the private sector. |
| E-participation* | Level of electronic participation. Measures the level of participation of citizens in public decisions and interaction with the government through digital means. |
| ICT use | It measures the prevalence of use of information and communication technologies (ICT) throughout society. |

Figure 1 shows the Flowchart for the IDOCRIW-CRADIS method.


**Fig. 1.** Flowchart of the proposed method

In the first stage of this study, IDOCRIW method was applied to obtain the weights of digital innovation performance indicators. Table 3 shows the weights obtained with the IDOCRIW method.

**Table 3**
Weights of Digital Innovation Performance Indicators

| Criterion | Code | IDOCRIW Weights |
|---|---|---|
| GitHub commits/mn pop. 15–69 | C1 | 0.055 |
| High-tech exports, % total trade | C2 | 0.109 |
| ICT services exports, % total trade | C3 | 0.109 |
| Software spending, % GDP | C4 | 0.129 |
| Mobile app creation/bn PPP$ GDP | C5 | 0.563 |
| University–industry R&D collaboration† | C6 | 0.012 |
| E-participation* | C7 | 0.02 |
| ICT use | C8 | 0.003 |

In the following step, CRADIS method was used to evaluate digital innovation performance of EU members and candidate countries. Table 4 shows the initial matrix.

**Table 4**
Initial Matrix

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Netherlands | 5104174 | 11.144 | 4.243 | 0.586 | 678349 | 5.414 | 0.966 | 87.998 |
| Republic of Moldova | 757872.4 | 0.711 | 6.424 | 0.077 | 1629014 | 3.123 | 0.682 | 82.167 |
| Albania | 415882.9 | 0.004 | 2.049 | 0.11 | 24289.06 | 4.339 | 0.761 | 80.171 |
| Austria | 3038108 | 8.071 | 3.505 | 0.6 | 377596.1 | 4.678 | 0.773 | 91.85 |
| Belgium | 3373124 | 12.7 | 3.291 | 0.606 | 93302.8 | 4.988 | 0.455 | 83.393 |
| Bosnia and Herzegovina | 509374 | 2.902 | 3.078 | 0.062 | 5687.675 | 2.609 | 0.534 | 76.601 |
| Bulgaria | 1736415 | 4.565 | 5.157 | 0.183 | 436545.1 | 3.905 | 0.739 | 87.73 |
| Croatia | 1569844 | 4.18 | 3.371 | 0.038 | 349070.5 | 2.992 | 0.739 | 91.496 |
| Cyprus | 2361466 | 0.861 | 27.972 | 0.135 | 90598014 | 3.767 | 0.75 | 83.971 |
| Czech Republic | 3416480 | 22.02 | 3.158 | 0.286 | 866435 | 4.771 | 0.602 | 85.687 |
| Denmark | 4008829 | 6.077 | 2.892 | 0.528 | 999388.9 | 5.049 | 0.886 | 94.08 |
| Estonia | 3917699 | 7.644 | 7.51 | 0.104 | 4722347 | 4.259 | 0.977 | 97.164 |
| Finland | 4983790 | 4.729 | 9.866 | 0.56 | 2267313 | 5.169 | 0.955 | 96.325 |
| France | 2635622 | 10.369 | 2.43 | 0.608 | 997596.6 | 4.37 | 0.716 | 88.274 |
| Georgia | 1839583 | 1.022 | 4.163 | 0.061 | 179144.6 | 4.293 | 0.534 | 86.663 |
| Germany | 3268516 | 12.815 | 2.08 | 0.545 | 389545.3 | 5.016 | 0.727 | 84.586 |
| Greece | 1213580 | 2.482 | 1.129 | 0.584 | 85967.55 | 3.131 | 0.614 | 84.068 |
| Hungary | 1704557 | 13.523 | 1.887 | 0.232 | 214110.4 | 4.178 | 0.511 | 83.094 |
| Ireland | 3110733 | 14.907 | 33.003 | 0.568 | 708411.6 | 4.708 | 0.682 | 83.968 |
| Italy | 1057906 | 7.496 | 1.296 | 0.636 | 229050 | 4.647 | 0.727 | 86.835 |
| Latvia | 2023735 | 6.914 | 4.359 | 0.091 | 1328993 | 3.75 | 0.739 | 94.293 |
| Lithuania | 2031927 | 7.102 | 2.97 | 0.061 | 3279092 | 4.656 | 0.545 | 95.126 |
| Luxembourg | 2590460 | 0.795 | 3.187 | 0.165 | 587054.7 | 4.98 | 0.75 | 87.862 |
| Malta | 1856578 | 4.158 | 1.276 | 0.298 | 992621.9 | 3.894 | 0.761 | 89.986 |
| Montenegro | 1867088 | 0.379 | 4.878 | 0.248 | 841776.2 | 3.482 | 0.466 | 86.921 |
| North Macedonia | 670964.8 | 2.526 | 4.273 | 0.104 | 292915.9 | 3.369 | 0.693 | 78.596 |
| Poland | 2134883 | 6.903 | 3.17 | 0.265 | 568556 | 3.616 | 0.648 | 93.956 |
| Portugal | 2383687 | 3.43 | 3.045 | 0.59 | 419934.2 | 4.185 | 0.727 | 84.451 |
| Romania | 1001375 | 6.377 | 7.038 | 0.264 | 365700.1 | 3.545 | 0.625 | 84.309 |
| Serbia | 1445134 | 2.607 | 6.479 | 0.031 | 738473.4 | 3.825 | 0.807 | 86.014 |
| Slovakia | 1189897 | 7.114 | 1.689 | 0.246 | 470011.8 | 3.202 | 0.466 | 82.926 |
| Slovenia | 2067468 | 7.236 | 1.762 | 0.063 | 1478170 | 4.114 | 0.75 | 88.86 |
| Spain | 2006673 | 6.458 | 2.827 | 0.587 | 612979.5 | 3.771 | 0.75 | 87.649 |
| Sweden | 4472775 | 8.414 | 6.918 | 0.57 | 2076410 | 5.053 | 0.727 | 93.675 |
| Türkiye | 383532.1 | 1.94 | 0.715 | 0.384 | 894953 | 3.529 | 0.784 | 84.503 |

Table 5 shows the normalized matrix.

**Table 5**
Normalized Matrix

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Netherlands | 1.000 | 0.506 | 0.129 | 0.921 | 0.007 | 1.000 | 0.989 | 0.906 |
| Republic of Moldova | 0.148 | 0.032 | 0.195 | 0.121 | 0.018 | 0.577 | 0.698 | 0.846 |
| Albania | 0.081 | 0.000 | 0.062 | 0.173 | 0.000 | 0.801 | 0.779 | 0.825 |
| Austria | 0.595 | 0.367 | 0.106 | 0.943 | 0.004 | 0.864 | 0.791 | 0.945 |
| Belgium | 0.661 | 0.577 | 0.100 | 0.953 | 0.001 | 0.921 | 0.466 | 0.858 |
| Bosnia and Herzegovina | 0.100 | 0.132 | 0.093 | 0.097 | 0.000 | 0.482 | 0.547 | 0.788 |
| Bulgaria | 0.340 | 0.207 | 0.156 | 0.288 | 0.005 | 0.721 | 0.756 | 0.903 |
| Croatia | 0.308 | 0.190 | 0.102 | 0.060 | 0.004 | 0.553 | 0.756 | 0.942 |
| Cyprus | 0.463 | 0.039 | 0.848 | 0.212 | 1.000 | 0.696 | 0.768 | 0.864 |
| Czech Republic | 0.669 | 1.000 | 0.096 | 0.450 | 0.010 | 0.881 | 0.616 | 0.882 |
| Denmark | 0.785 | 0.276 | 0.088 | 0.830 | 0.011 | 0.933 | 0.907 | 0.968 |
| Estonia | 0.768 | 0.347 | 0.228 | 0.164 | 0.052 | 0.787 | 1.000 | 1.000 |
| Finland | 0.976 | 0.215 | 0.299 | 0.881 | 0.025 | 0.955 | 0.977 | 0.991 |
| France | 0.516 | 0.471 | 0.074 | 0.956 | 0.011 | 0.807 | 0.733 | 0.909 |
| Georgia | 0.360 | 0.046 | 0.126 | 0.096 | 0.002 | 0.793 | 0.547 | 0.892 |
| Germany | 0.640 | 0.582 | 0.063 | 0.857 | 0.004 | 0.926 | 0.744 | 0.871 |
| Greece | 0.238 | 0.113 | 0.034 | 0.918 | 0.001 | 0.578 | 0.628 | 0.865 |
| Hungary | 0.334 | 0.614 | 0.057 | 0.365 | 0.002 | 0.772 | 0.523 | 0.855 |
| Ireland | 0.609 | 0.677 | 1.000 | 0.893 | 0.008 | 0.870 | 0.698 | 0.864 |
| Italy | 0.207 | 0.340 | 0.039 | 1.000 | 0.003 | 0.858 | 0.744 | 0.894 |
| Latvia | 0.396 | 0.314 | 0.132 | 0.143 | 0.015 | 0.693 | 0.756 | 0.970 |
| Lithuania | 0.398 | 0.323 | 0.090 | 0.096 | 0.036 | 0.860 | 0.558 | 0.979 |
| Luxembourg | 0.508 | 0.036 | 0.097 | 0.259 | 0.006 | 0.920 | 0.768 | 0.904 |
| Malta | 0.364 | 0.189 | 0.039 | 0.469 | 0.011 | 0.719 | 0.779 | 0.926 |
| Montenegro | 0.366 | 0.017 | 0.148 | 0.390 | 0.009 | 0.643 | 0.477 | 0.895 |
| North Macedonia | 0.131 | 0.115 | 0.129 | 0.164 | 0.003 | 0.622 | 0.709 | 0.809 |
| Poland | 0.418 | 0.313 | 0.096 | 0.417 | 0.006 | 0.668 | 0.663 | 0.967 |
| Portugal | 0.467 | 0.156 | 0.092 | 0.928 | 0.005 | 0.773 | 0.744 | 0.869 |
| Romania | 0.196 | 0.290 | 0.213 | 0.415 | 0.004 | 0.655 | 0.640 | 0.868 |
| Serbia | 0.283 | 0.118 | 0.196 | 0.049 | 0.008 | 0.707 | 0.826 | 0.885 |
| Slovakia | 0.233 | 0.323 | 0.051 | 0.387 | 0.005 | 0.591 | 0.477 | 0.853 |
| Slovenia | 0.405 | 0.329 | 0.053 | 0.099 | 0.016 | 0.760 | 0.768 | 0.915 |
| Spain | 0.393 | 0.293 | 0.086 | 0.923 | 0.007 | 0.697 | 0.768 | 0.902 |
| Sweden | 0.876 | 0.382 | 0.210 | 0.896 | 0.023 | 0.933 | 0.744 | 0.964 |
| Türkiye | 0.075 | 0.088 | 0.022 | 0.604 | 0.010 | 0.652 | 0.802 | 0.870 |

Table 6 shows the weighted normalized matrix.

**Table 6**
Weighted Normalized Matrix

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Netherlands | 0.055 | 0.055 | 0.014 | 0.119 | 0.004 | 0.012 | 0.020 | 0.003 |
| Republic of Moldova | 0.008 | 0.004 | 0.021 | 0.016 | 0.010 | 0.007 | 0.014 | 0.003 |
| Albania | 0.004 | 0.000 | 0.007 | 0.022 | 0.000 | 0.010 | 0.016 | 0.002 |
| Austria | 0.033 | 0.040 | 0.012 | 0.122 | 0.002 | 0.010 | 0.016 | 0.003 |
| Belgium | 0.036 | 0.063 | 0.011 | 0.123 | 0.001 | 0.011 | 0.009 | 0.003 |
| Bosnia and Herzegovina | 0.005 | 0.014 | 0.010 | 0.013 | 0.000 | 0.006 | 0.011 | 0.002 |

**Table 6**
Continued

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Bulgaria | 0.019 | 0.023 | 0.017 | 0.037 | 0.003 | 0.009 | 0.015 | 0.003 |
| Croatia | 0.017 | 0.021 | 0.011 | 0.008 | 0.002 | 0.007 | 0.015 | 0.003 |
| Cyprus | 0.025 | 0.004 | 0.092 | 0.027 | 0.563 | 0.008 | 0.015 | 0.003 |
| Czech Republic | 0.037 | 0.109 | 0.010 | 0.058 | 0.005 | 0.011 | 0.012 | 0.003 |
| Denmark | 0.043 | 0.030 | 0.010 | 0.107 | 0.006 | 0.011 | 0.018 | 0.003 |
| Estonia | 0.042 | 0.038 | 0.025 | 0.021 | 0.029 | 0.009 | 0.020 | 0.003 |
| Finland | 0.054 | 0.023 | 0.033 | 0.114 | 0.014 | 0.011 | 0.020 | 0.003 |
| France | 0.028 | 0.051 | 0.008 | 0.123 | 0.006 | 0.010 | 0.015 | 0.003 |
| Georgia | 0.020 | 0.005 | 0.014 | 0.012 | 0.001 | 0.010 | 0.011 | 0.003 |
| Germany | 0.035 | 0.063 | 0.007 | 0.111 | 0.002 | 0.011 | 0.015 | 0.003 |
| Greece | 0.013 | 0.012 | 0.004 | 0.118 | 0.001 | 0.007 | 0.013 | 0.003 |
| Hungary | 0.018 | 0.067 | 0.006 | 0.047 | 0.001 | 0.009 | 0.010 | 0.003 |
| Ireland | 0.034 | 0.074 | 0.109 | 0.115 | 0.004 | 0.010 | 0.014 | 0.003 |
| Italy | 0.011 | 0.037 | 0.004 | 0.129 | 0.001 | 0.010 | 0.015 | 0.003 |
| Latvia | 0.022 | 0.034 | 0.014 | 0.018 | 0.008 | 0.008 | 0.015 | 0.003 |
| Lithuania | 0.022 | 0.035 | 0.010 | 0.012 | 0.020 | 0.010 | 0.011 | 0.003 |
| Luxembourg | 0.028 | 0.004 | 0.011 | 0.033 | 0.004 | 0.011 | 0.015 | 0.003 |
| Malta | 0.020 | 0.021 | 0.004 | 0.060 | 0.006 | 0.009 | 0.016 | 0.003 |
| Montenegro | 0.020 | 0.002 | 0.016 | 0.050 | 0.005 | 0.008 | 0.010 | 0.003 |
| North Macedonia | 0.007 | 0.013 | 0.014 | 0.021 | 0.002 | 0.007 | 0.014 | 0.002 |
| Poland | 0.023 | 0.034 | 0.010 | 0.054 | 0.004 | 0.008 | 0.013 | 0.003 |
| Portugal | 0.026 | 0.017 | 0.010 | 0.120 | 0.003 | 0.009 | 0.015 | 0.003 |
| Romania | 0.011 | 0.032 | 0.023 | 0.054 | 0.002 | 0.008 | 0.013 | 0.003 |
| Serbia | 0.016 | 0.013 | 0.021 | 0.006 | 0.005 | 0.008 | 0.017 | 0.003 |
| Slovakia | 0.013 | 0.035 | 0.006 | 0.050 | 0.003 | 0.007 | 0.010 | 0.003 |
| Slovenia | 0.022 | 0.036 | 0.006 | 0.013 | 0.009 | 0.009 | 0.015 | 0.003 |
| Spain | 0.022 | 0.032 | 0.009 | 0.119 | 0.004 | 0.008 | 0.015 | 0.003 |
| Sweden | 0.048 | 0.042 | 0.023 | 0.116 | 0.013 | 0.011 | 0.015 | 0.003 |
| Türkiye | 0.004 | 0.010 | 0.002 | 0.078 | 0.006 | 0.008 | 0.016 | 0.003 |

Table 7 shows the deviations from the ideal solution.

**Table 7**
Deviations from the Ideal Solution

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Netherlands | 0.508 | 0.508 | 0.549 | 0.444 | 0.559 | 0.551 | 0.543 | 0.560 |
| Republic of Moldova | 0.555 | 0.559 | 0.542 | 0.547 | 0.553 | 0.556 | 0.549 | 0.560 |
| Albania | 0.559 | 0.563 | 0.556 | 0.541 | 0.563 | 0.553 | 0.547 | 0.561 |
| Austria | 0.530 | 0.523 | 0.551 | 0.441 | 0.561 | 0.553 | 0.547 | 0.560 |
| Belgium | 0.527 | 0.500 | 0.552 | 0.440 | 0.562 | 0.552 | 0.554 | 0.560 |
| Bosnia and Herzegovina | 0.558 | 0.549 | 0.553 | 0.550 | 0.563 | 0.557 | 0.552 | 0.561 |
| Bulgaria | 0.544 | 0.540 | 0.546 | 0.526 | 0.560 | 0.554 | 0.548 | 0.560 |
| Croatia | 0.546 | 0.542 | 0.552 | 0.555 | 0.561 | 0.556 | 0.548 | 0.560 |
| Cyprus | 0.538 | 0.559 | 0.471 | 0.536 | 0.000 | 0.555 | 0.548 | 0.560 |
| Czech Republic | 0.526 | 0.454 | 0.553 | 0.505 | 0.558 | 0.552 | 0.551 | 0.560 |
| Denmark | 0.520 | 0.533 | 0.553 | 0.456 | 0.557 | 0.552 | 0.545 | 0.560 |
| Estonia | 0.521 | 0.525 | 0.538 | 0.542 | 0.534 | 0.554 | 0.543 | 0.560 |
| Finland | 0.509 | 0.540 | 0.530 | 0.449 | 0.549 | 0.552 | 0.543 | 0.560 |
| France | 0.535 | 0.512 | 0.555 | 0.440 | 0.557 | 0.553 | 0.548 | 0.560 |
| Georgia | 0.543 | 0.558 | 0.549 | 0.551 | 0.562 | 0.553 | 0.552 | 0.560 |
| Germany | 0.528 | 0.500 | 0.556 | 0.452 | 0.561 | 0.552 | 0.548 | 0.560 |
| Greece | 0.550 | 0.551 | 0.559 | 0.445 | 0.562 | 0.556 | 0.550 | 0.560 |

**Table 7**
Continued

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Hungary | 0.545 | 0.496 | 0.557 | 0.516 | 0.562 | 0.554 | 0.553 | 0.560 |
| Ireland | 0.529 | 0.489 | 0.454 | 0.448 | 0.559 | 0.553 | 0.549 | 0.560 |
| Italy | 0.552 | 0.526 | 0.559 | 0.434 | 0.562 | 0.553 | 0.548 | 0.560 |
| Latvia | 0.541 | 0.529 | 0.549 | 0.545 | 0.555 | 0.555 | 0.548 | 0.560 |
| Lithuania | 0.541 | 0.528 | 0.553 | 0.551 | 0.543 | 0.553 | 0.552 | 0.560 |
| Luxembourg | 0.535 | 0.559 | 0.552 | 0.530 | 0.559 | 0.552 | 0.548 | 0.560 |
| Malta | 0.543 | 0.542 | 0.559 | 0.503 | 0.557 | 0.554 | 0.547 | 0.560 |
| Montenegro | 0.543 | 0.561 | 0.547 | 0.513 | 0.558 | 0.555 | 0.553 | 0.560 |
| North Macedonia | 0.556 | 0.550 | 0.549 | 0.542 | 0.561 | 0.556 | 0.549 | 0.561 |
| Poland | 0.540 | 0.529 | 0.553 | 0.509 | 0.559 | 0.555 | 0.550 | 0.560 |
| Portugal | 0.537 | 0.546 | 0.553 | 0.443 | 0.560 | 0.554 | 0.548 | 0.560 |
| Romania | 0.552 | 0.531 | 0.540 | 0.509 | 0.561 | 0.555 | 0.550 | 0.560 |
| Serbia | 0.547 | 0.550 | 0.542 | 0.557 | 0.558 | 0.555 | 0.546 | 0.560 |
| Slovakia | 0.550 | 0.528 | 0.557 | 0.513 | 0.560 | 0.556 | 0.553 | 0.560 |
| Slovenia | 0.541 | 0.527 | 0.557 | 0.550 | 0.554 | 0.554 | 0.548 | 0.560 |
| Spain | 0.541 | 0.531 | 0.554 | 0.444 | 0.559 | 0.555 | 0.548 | 0.560 |
| Sweden | 0.515 | 0.521 | 0.540 | 0.447 | 0.550 | 0.552 | 0.548 | 0.560 |
| Türkiye | 0.559 | 0.553 | 0.561 | 0.485 | 0.557 | 0.555 | 0.547 | 0.560 |

Table 8 indicates the deviations from the anti-ideal solution.

**Table 8**
Deviations from the Anti Ideal Solution

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Netherlands | 0.055 | 0.055 | 0.014 | 0.119 | 0.004 | 0.012 | 0.020 | 0.003 |
| Republic of Moldova | 0.008 | 0.003 | 0.021 | 0.016 | 0.010 | 0.007 | 0.014 | 0.003 |
| Albania | 0.004 | 0.000 | 0.007 | 0.022 | 0.000 | 0.010 | 0.016 | 0.002 |
| Austria | 0.033 | 0.040 | 0.012 | 0.122 | 0.002 | 0.010 | 0.016 | 0.003 |
| Belgium | 0.036 | 0.063 | 0.011 | 0.123 | 0.001 | 0.011 | 0.009 | 0.003 |
| Bosnia and Herzegovina | 0.005 | 0.014 | 0.010 | 0.013 | 0.000 | 0.006 | 0.011 | 0.002 |
| Bulgaria | 0.019 | 0.023 | 0.017 | 0.037 | 0.003 | 0.009 | 0.015 | 0.003 |
| Croatia | 0.017 | 0.021 | 0.011 | 0.008 | 0.002 | 0.007 | 0.015 | 0.003 |
| Cyprus | 0.025 | 0.004 | 0.092 | 0.027 | 0.563 | 0.008 | 0.015 | 0.003 |
| Czech Republic | 0.037 | 0.109 | 0.010 | 0.058 | 0.005 | 0.011 | 0.012 | 0.003 |
| Denmark | 0.043 | 0.030 | 0.010 | 0.107 | 0.006 | 0.011 | 0.018 | 0.003 |
| Estonia | 0.042 | 0.038 | 0.025 | 0.021 | 0.029 | 0.009 | 0.020 | 0.003 |
| Finland | 0.054 | 0.023 | 0.033 | 0.114 | 0.014 | 0.011 | 0.020 | 0.003 |
| France | 0.028 | 0.051 | 0.008 | 0.123 | 0.006 | 0.010 | 0.015 | 0.003 |
| Georgia | 0.020 | 0.005 | 0.014 | 0.012 | 0.001 | 0.009 | 0.011 | 0.003 |
| Germany | 0.035 | 0.063 | 0.007 | 0.111 | 0.002 | 0.011 | 0.015 | 0.003 |
| Greece | 0.013 | 0.012 | 0.004 | 0.118 | 0.001 | 0.007 | 0.013 | 0.003 |
| Hungary | 0.018 | 0.067 | 0.006 | 0.047 | 0.001 | 0.009 | 0.010 | 0.003 |
| Ireland | 0.033 | 0.074 | 0.109 | 0.115 | 0.004 | 0.010 | 0.014 | 0.003 |
| Italy | 0.011 | 0.037 | 0.004 | 0.129 | 0.001 | 0.010 | 0.015 | 0.003 |
| Latvia | 0.022 | 0.034 | 0.014 | 0.018 | 0.008 | 0.008 | 0.015 | 0.003 |
| Lithuania | 0.022 | 0.035 | 0.010 | 0.012 | 0.020 | 0.010 | 0.011 | 0.003 |
| Luxembourg | 0.028 | 0.004 | 0.011 | 0.033 | 0.004 | 0.011 | 0.015 | 0.003 |
| Malta | 0.020 | 0.021 | 0.004 | 0.060 | 0.006 | 0.009 | 0.016 | 0.003 |
| Montenegro | 0.020 | 0.002 | 0.016 | 0.050 | 0.005 | 0.008 | 0.010 | 0.003 |
| North Macedonia | 0.007 | 0.012 | 0.014 | 0.021 | 0.002 | 0.007 | 0.014 | 0.002 |
| Poland | 0.023 | 0.034 | 0.010 | 0.054 | 0.004 | 0.008 | 0.013 | 0.003 |
| Portugal | 0.026 | 0.017 | 0.010 | 0.120 | 0.003 | 0.009 | 0.015 | 0.003 |

**Table 8**
Continued

| Countries | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| Romania | 0.011 | 0.032 | 0.023 | 0.054 | 0.002 | 0.008 | 0.013 | 0.003 |
| Serbia | 0.016 | 0.013 | 0.021 | 0.006 | 0.005 | 0.008 | 0.017 | 0.003 |
| Slovakia | 0.013 | 0.035 | 0.006 | 0.050 | 0.003 | 0.007 | 0.010 | 0.003 |
| Slovenia | 0.022 | 0.036 | 0.006 | 0.013 | 0.009 | 0.009 | 0.015 | 0.003 |
| Spain | 0.022 | 0.032 | 0.009 | 0.119 | 0.004 | 0.008 | 0.015 | 0.003 |
| Sweden | 0.048 | 0.042 | 0.023 | 0.116 | 0.013 | 0.011 | 0.015 | 0.003 |
| Türkiye | 0.004 | 0.010 | 0.002 | 0.078 | 0.006 | 0.008 | 0.016 | 0.003 |

Table 9 shows the degrees of deviation from ideal and anti-ideal solutions ($s_i^+$, $s_i^-$), utility function for each alternative ($K_i^+$, $K_i^-$) and final rank ($Q_i$ ).

**Table 9**
CRADIS results

| Countries | $s_i^+$ | $K_i^+$ | $s_i^-$ | $K_i^-$ | $Q_i$ | Rank |
|---|---|---|---|---|---|---|
| Netherlands | 4.222 | 0.830 | 0.282 | 0.282 | 0.556 | 3 |
| Republic of Moldova | 4.422 | 0.792 | 0.082 | 0.082 | 0.437 | 31 |
| Albania | 4.443 | 0.789 | 0.061 | 0.061 | 0.425 | 35 |
| Austria | 4.267 | 0.821 | 0.237 | 0.237 | 0.529 | 10 |
| Belgium | 4.247 | 0.825 | 0.256 | 0.256 | 0.541 | 6 |
| Bosnia and Herzegovina | 4.442 | 0.789 | 0.062 | 0.062 | 0.425 | 34 |
| Bulgaria | 4.379 | 0.800 | 0.125 | 0.125 | 0.462 | 23 |
| Croatia | 4.421 | 0.793 | 0.083 | 0.083 | 0.438 | 30 |
| Cyprus | 3.765 | 0.931 | 0.739 | 0.739 | 0.835 | 1 |
| Czech Republic | 4.259 | 0.823 | 0.245 | 0.245 | 0.534 | 8 |
| Denmark | 4.276 | 0.820 | 0.228 | 0.228 | 0.524 | 11 |
| Estonia | 4.316 | 0.812 | 0.188 | 0.188 | 0.500 | 15 |
| Finland | 4.233 | 0.828 | 0.271 | 0.271 | 0.550 | 4 |
| France | 4.260 | 0.823 | 0.244 | 0.244 | 0.533 | 9 |
| Georgia | 4.429 | 0.791 | 0.075 | 0.075 | 0.433 | 33 |
| Germany | 4.257 | 0.823 | 0.247 | 0.247 | 0.535 | 7 |
| Greece | 4.334 | 0.809 | 0.170 | 0.170 | 0.489 | 16 |
| Hungary | 4.342 | 0.807 | 0.162 | 0.162 | 0.485 | 17 |
| Ireland | 4.141 | 0.846 | 0.363 | 0.363 | 0.604 | 2 |
| Italy | 4.293 | 0.816 | 0.211 | 0.211 | 0.514 | 13 |
| Latvia | 4.381 | 0.800 | 0.123 | 0.123 | 0.462 | 25 |
| Lithuania | 4.380 | 0.800 | 0.124 | 0.124 | 0.462 | 24 |
| Luxembourg | 4.395 | 0.797 | 0.108 | 0.108 | 0.453 | 28 |
| Malta | 4.366 | 0.803 | 0.138 | 0.138 | 0.470 | 20 |
| Montenegro | 4.390 | 0.798 | 0.113 | 0.113 | 0.456 | 26 |
| North Macedonia | 4.423 | 0.792 | 0.081 | 0.081 | 0.436 | 32 |
| Poland | 4.355 | 0.805 | 0.149 | 0.149 | 0.477 | 18 |
| Portugal | 4.302 | 0.814 | 0.202 | 0.202 | 0.508 | 14 |
| Romania | 4.359 | 0.804 | 0.145 | 0.145 | 0.474 | 19 |
| Serbia | 4.416 | 0.794 | 0.088 | 0.088 | 0.441 | 29 |
| Slovakia | 4.378 | 0.800 | 0.125 | 0.125 | 0.463 | 22 |
| Slovenia | 4.391 | 0.798 | 0.113 | 0.113 | 0.455 | 27 |
| Spain | 4.292 | 0.816 | 0.212 | 0.212 | 0.514 | 12 |
| Sweden | 4.234 | 0.828 | 0.270 | 0.270 | 0.549 | 5 |
| Türkiye | 4.378 | 0.800 | 0.126 | 0.126 | 0.463 | 21 |
| OA | 3.504 | | | 0.999 | | |

In this study, a comparative analysis was conducted to evaluate the impact of different MCDM methods on the rankings of countries. The methods used include CRADIS, COBRA, WEDBA, SAW, CoCoSo and TOPSIS. Figure 2 aims to visualize the ranking similarities and differences between the methods, showing which countries experience higher ranking variability and which countries yield more consistent results.

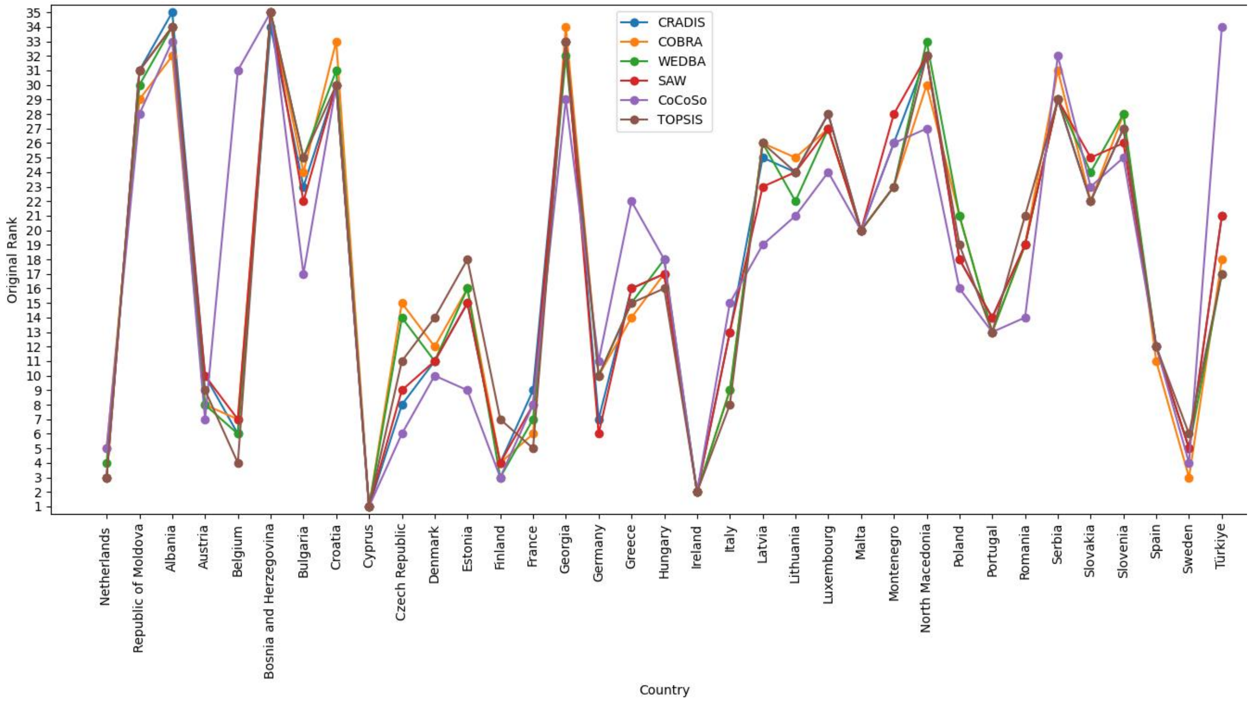


**Fig. 2.** The Ranking Results of Countries According to Different MCDM Methods

As seen in Figure 2, the ranking trends of the methods are generally similar. In particular, the ranking results of the methods are largely consistent in countries such as Cyprus, Netherlands, Finland, Germany, Sweden, Denmark, France, and Ireland. This shows that the digital innovation performance of these countries is generally superior and the rankings are stable among different MCDM methods. On the other hand, remarkable ranking differences were observed between the methods in countries such as Albania, Austria, Greece, Bulgaria, Montenegro, North Macedonia, Georgia, Italy, and Türkiye. For example, in Türkiye, some methods position the country in the upper ranks, while others rank it lower. Figure 3 presents the correlation results between rankings obtained with different MCDM methods.

According to Figure 3, there is a high correlation between the ranking results of different MCDM methods.

A sensitivity analysis was carried out to examine the changes in the rankings of the alternatives [47]. The scenarios for the two critical criteria with the highest and lowest weights were applied with the IDOCRIW method. In this way, the effects of changes in the weights of the critical criteria on the ranking were evaluated and the stability of the model was tested. The weights for these two critical criteria (C5: Mobile app creation/bn PPP$ GDP and C8: ICT use) were changed by 30%, 60% and 90%, respectively, and the rankings of the alternatives were observed for each scenario. Figure 4 shows the trend in the ranking changes across scenarios.

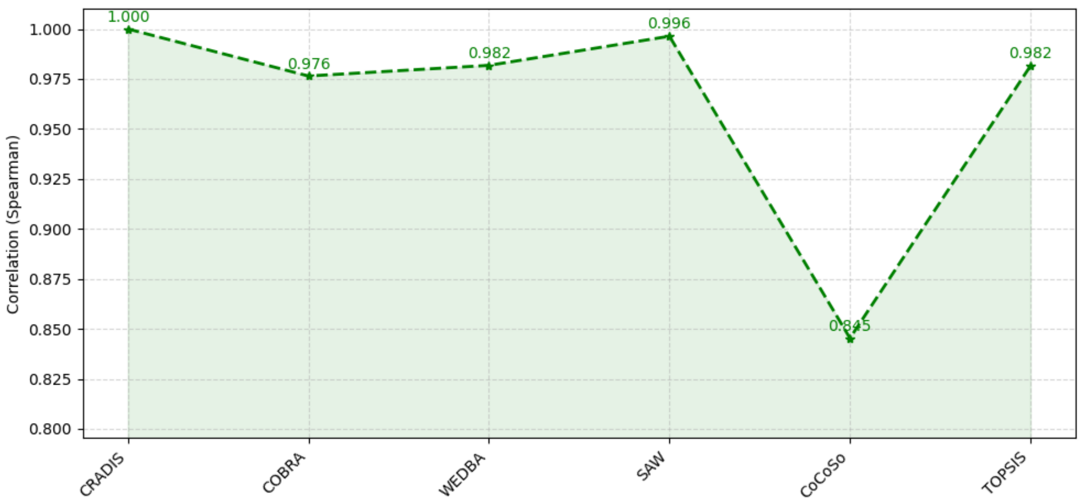


Fig. 3. Spearman's Rank Correlation among MCDM Methods

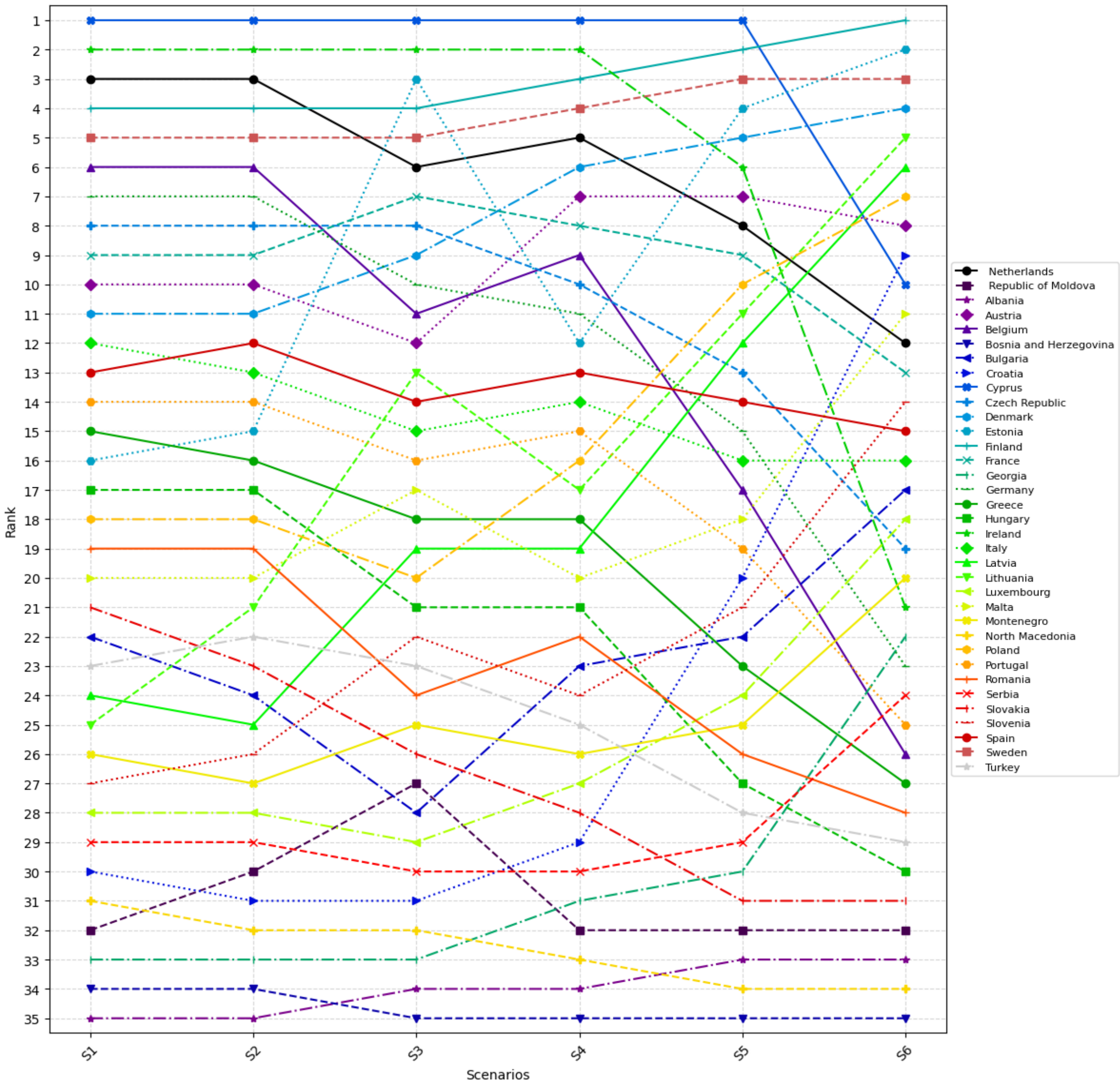


**Fig. 4.** Sensitivity Analysis: Country Rankings Based on Criteria Weight

It is observed that the rankings of most countries remain stable, but there are notable changes in the rankings of some countries. Some fluctuations in the rankings occur, especially when the weights of the highest and lowest weighted criteria are changed. This suggests that certain criteria have a greater impact on the model results and have the potential to affect the rankings.

**5. Conclusions**

This study proposed an integrated approach to evaluate digital innovation performance across European Union (EU) members and candidate countries by combining the IDOCRIW and CRADIS methods. The use of objective weighting methods (Entropy and CILOS) through the IDOCRIW model, combined with the CRADIS ranking methodology, enables a more comprehensive and robust evaluation framework for complex multi-criteria problems like digital innovation performance assessment.

The selection of criteria directly linked to digital innovation from the Global Innovation Index (GII) 2024 ensures a focused and contemporary measurement of performance. The indicators used — including software spending, mobile application development, high-tech exports, ICT service exports, GitHub activity, university–industry R&D collaboration, e-participation, and ICT use — collectively reflect both the technological capabilities and digital ecosystem maturity of each country.

The results reveal stark contrasts between countries. Cyprus, Ireland, Netherlands, Finland and Sweden are found to be the top five countries in digital innovation performance, indicating their strong alignment of national strategies with technological investments and innovation ecosystems. Conversely, countries such as Albania, Bosnia and Herzegovina, and the Georgia occupy the lowest ranks, highlighting the challenges faced by some candidate or neighboring countries in adapting to rapidly evolving digital standards.

The findings emphasize the importance of investing not only in digital infrastructure but also in supportive policies that foster collaboration between academia, industry, and government. Moreover, the considerable weight assigned to the “mobile app creation” indicator in the IDOCRIW weighting process reflects the increasing significance of entrepreneurial and agile innovation activities in digital economies.

The integrated IDOCRIW–CRADIS model presented here contributes methodologically by addressing the limitations of single-method evaluations and offering greater stability and consistency in ranking results. This model can serve as a reliable tool for policymakers, researchers, and practitioners interested in benchmarking innovation performance, diagnosing weaknesses, and identifying strategic improvement areas.

Future studies may apply this hybrid methodology to evaluate digital innovation performance at sectoral levels (e.g., health tech, fintech), across other economic blocks, or in post-pandemic transformation contexts. Additionally, integrating fuzzy or probabilistic techniques into the model could further enhance its adaptability to uncertainty in innovation environments.

In conclusion, the study not only offers empirical insights into the digital innovation landscape of the EU and its candidate countries but also contributes to the growing literature on MCDM in the field of innovation policy and digital transformation.

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**Conflicts of Interest**
The authors declare no conflicts of interest.

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