International Journal of Business & Economic Studies
Year: 2025, Vol: 7, No: 3, pp.172-187
https://doi.org/10.54821/uiecd.1727403

# Evaluating Information and Communication Technology (ICT) Levels in Visegrad Countries: A Performance Analysis Using MPSI-LOPCOW-BSS Framework

*Visegrad Ülkelerinde Bilgi ve İletişim Teknolojileri (ICT) Düzeylerinin Değerlendirilmesi: MPSI-LOPCOW-BSS Çerçevesini Kullanarak Performans Analizi*

**Mehmet Akif KARA**
*Asst. Prof. Dr., Giresun University*
akifkara28@gmail.com
https://orcid.org/0000-0003-4308-9933

Received : 25.06.2025
Revised : 17.09.2025
Accepted : 27.09.2025
Type of Article : Research

***Keywords:***
*Information and Communication Technology,*
*Multi-Criteria Decision Methods,*
*Decision Support Systems,*
*Visegrad Countries*
***Jel Codes:***
*C02, C44, D80*

**ABSTRACT**

*Information and Communication Technologies (ICT) are the keys to the competitiveness of both states and businesses. The rapid advancements and developments in technology and communication have led to the emergence of information and communication technologies. The policymaking authorities are making the proper arrangements for the maintenance and growth of the infrastructure for information and communication technologies. In this view, the study and assessment of the ICT levels of different countries become a fundamental issue. Therefore, this project is an in-depth study of the Visegrad countries ICT performance, which was analyzed using the selected list of criteria which included; ICT employment, ICT investment, ICT value-added, ICT goods exports, internet access, and home computer access. In this research, the MPSI and LOPCOW methods were applied to determine the weights of the criteria, which were then combined with an aggregation operator to derive the final criteria weights. Soon afterward, the countries' ICT levels were ranked by means of the BSS method. The study proposes an integrated MPSI-LOPCOW-BSS decision support system. As a result of the application, the criterion with the highest weight was found to be "ICT Investment." The country rankings are Czechia, Hungary, Poland, and Slovakia.*

***Anahtar Kelimeler:***
*Bilgi ve İletişim Teknolojisi,*
*Çok Kriterli Karar Verme Yöntemleri,*
*Karar Destek Sistemleri,*
*Visegrad Ülkeleri*
***Jel Kodları:***
*C02, C44, D80*

**ÖZET**

*Bilgi ve İletişim Teknolojileri (ICT), hem devletlerin hem de işletmelerin rekabetçiliği için anahtar konumundadır. Teknoloji ve iletişimdeki hızlı gelişmeler, bilgi ve iletişim teknolojilerinin ortaya çıkmasına yol açmıştır. Politika yapıcı otoriteler, bilgi ve iletişim teknolojileri altyapısının sürdürülebilirliği ve büyümesi için uygun düzenlemeleri yapmaktadır. Bu bağlamda, farklı ülkelerin ICT düzeylerinin incelenmesi ve değerlendirilmesi temel bir konu haline gelmektedir. Bu nedenle, bu proje Visegrad ülkelerinin ICT performansını derinlemesine incelemektedir. Analiz, ICT istihdamı, ICT yatırımı, ICT katma değeri, ICT mal ihracatı, internet erişimi ve ev bilgisayarı erişimi gibi belirlenen kriterler kullanılarak gerçekleştirilmiştir. Araştırmada, kriterlerin ağırlıklarını belirlemek için MPSI ve LOPCOW yöntemleri uygulanmış ve ardından nihai kriter ağırlıklarını elde etmek için bir toplama operatörü ile birleştirilmiştir. Daha sonra, ülkelerin ICT seviyeleri BSS yöntemi ile sıralanmıştır. Çalışma, entegre bir MPSI-LOPCOW-BSS karar destek sistemi önermektedir. Uygulama sonucunda en yüksek ağırlığa sahip kriterin "ICT Yatırımı" olduğu bulunmuştur. Ülke sıralamaları ise Çek Cumhuriyeti, Polonya, Macaristan ve Slovakya'dır.*

**Suggested Citation:** Kara, M. A. (2025). The evaluating information and communication technology (ICT) levels in Visegrad countries: A performance analysis using MPSI-LOPCOW-BSS framework. *International Journal of Business and Economic Studies*, 7(3), 172-187, https://doi.org/10.54821/uiecd.1727403

# 1. INTRODUCTION

The rise of globalization have made information and communication technologies (ICTs) pivotal and indeed have become an essential complementary of the context of rapid technological and economic advancements. Nour (2005) states that the most important way to catch up to the industrial economies in development in ICT. Hence, the production and export of the ICT goods are significant competitive factors for countries (Batbaylı, 2024), while the countries that are faced with the problem of lacking technology necessarily spend a huge amount on the importation of necessary goods (Heeks, 2010). The digital convergence process, initiated in the 1980s, revolutionized the processing of text, audio, and images in digital formats. This, combined with the digitalization of telecommunications, enabled the transmission of digital data and information. As a result, information technology and communication technology have become increasingly intertwined, a phenomenon captured by the term ICT. ICT encompasses the processes of processing, storing, transmitting, and presenting various forms of information, including voice, data, text, and images, through hardware, software, networks, and media.

The globalization of markets has been accelerated by the widespread adoption of ICT (Lal, 2007). ICT plays a crucial role in facilitating the collection, processing, storage, and transfer of information among organizations, thereby enhancing access to international trade and fostering collaboration (Harris et al., 2015). This integration allows countries to participate in global markets and the international workforce, driven by technological advancements. Additionally, ICT offers significant advantages to businesses, particularly in terms of efficiency and innovation (Perego et al., 2011). The integration of technology has led to the emergence of new business opportunities and models, triggering transformations in traditional sectors and impacting economic dynamics. Investments in information technologies can further promote sustainable and inclusive economic growth. In recent years, the rapid global proliferation of ICT has had profound effects on both individuals and businesses. The increased use of these technologies is particularly notable in the context of e-commerce and the adaptation of government public operations to new technologies, both of which are critical factors influencing competition (Chen et al., 2021). The initial phase of the digitalization process involved the integration of the Internet and computers into daily life, followed by advancements in software systems and automation that facilitated the development of innovative business models and the rapid dissemination of digital concepts (Klein, 2020).

Information and communication technology provides several key benefits (Demir, 2022): "*(i) rapid and efficient data processing capabilities; (ii) the transformation of information into valuable services, enhancing convenience; (iii) human-centered applications in product and service development, thereby increasing productivity; (iv) rapid identification of errors through analyses conducted in business environments; and (v) rapid access to information, facilitating knowledge sharing*". Evaluating ICT levels in countries is essential for effective strategic policy formulation and planning, as understanding the current state of ICT levels sheds light on policy development.

The primary aim of this study is to develop a hybrid decision support system for determining the Information and Communication Technology (ICT) levels of Visegrad (V4) countries.

This decision support system incorporates multi-criteria decision-making (MCDM) methods that are relatively new to the literature in terms of criteria weighting and ranking, as determining ICT levels is a typical decision-making process. The sub-objectives of the study are as follows:

*Case Study Application*: To conduct a case study to determine the ICT levels of V4 countries. This study focuses on the Visegrad countries: the Czechia, Hungary, Poland, and Slovakia. The reasons for selecting this sample group include their geographical and cultural proximity, their significant role in EU economic cooperation and integration, their advancements in the ICT sector in recent years, and the opportunity to analyze differences in ICT levels due to historical reform processes and economic developments in the post-communist era. Additionally, the similar structural characteristics among the Visegrad countries ensure the validity and reliability of the rankings performed using multi-criteria decision-making methods.

*Methodological Development in MCDM*: To contribute to the methodological advancement of MCDM methods, particularly by using two different criteria weighting methods together to determine a final criterion weight. The study also proposes the development of the MPSI-LOPCOW-BSS hybrid method to assess the ICT levels of countries. In this study, the MPSI and LOPCOW methods were chosen for criterion weighting. The MPSI method is selected because it performs simple and effective calculations in the criterion weighting process. It is an improved version of the PSI method, where a step was removed to enhance the accuracy of the final weight coefficients. It aligns closely with other objective weighting methods and considers deviations among the normalized values of the criteria during calculations. The LOPCOW method is preferred because it uses a logarithmic function to calculate the standard deviation for each criterion, ensuring more meaningful and accurate percentage values. Its simple three-step structure makes it easier for practitioners to follow. The BSS method, chosen for ranking, is relatively new and has been used in very few studies.

*Criterion Weighting Approach:* The study combines two different objective criterion weighting methods in the decision model.

*Final Criterion Weight Calculation*: The study calculates final criterion weights by integrating the MPSI and LOPCOW methods, offering a comprehensive criterion weighting approach. The main reason for combining both methods is their suitability for sensitivity analysis.

*ICT Levels Scoring:* The study utilizes the BSS method to obtain and rank the ICT levels of countries.

*Methodological Contribution*: This study provides methodological contributions to the fields of information and communication technologies and multi-criteria decision-making approaches, further developing decision support systems in this area.

This study makes several significant contributions to the literature. First, it uses a multi-criteria decision-making (MCDM) approach to evaluate ICT development. Second, it identifies the most important indicators for assessing ICT development in social and economic contexts. Third, it develops an integrated MCDM framework using the MPSI-LOPCOW-BSS methods. Unlike traditional qualitative assessments, this study uses real data obtained from OECD datasets. The MPSI and LOPCOW methods are applied to determine the optimal weighting coefficients of the indicators, followed by the calculation of the final criteria weights using an aggregation operator. Subsequently, real data from the OECD dataset is analyzed using the BSS model to evaluate ICT development, and countries are prioritized according to their performance based on the identified indicators. The contributions of the proposed decision-making model are:

- An actual case study assessing ICT development through social and economic metrics.
- A dependable integrated MCDM framework utilizing the MPSI-LOPCOW-BSS methods.
- Benchmarking to evaluate ICT development in the Visegrad countries.
- Suggestions and strategies for enhancing ICT tools and services across different sectors based on the study's findings.

The proposed methodology and identified indicators can serve as benchmarking case studies for other groups of countries. In summary, this study aims to achieve two main objectives: to evaluate the IT levels of the Visegrad countries and to develop a decision support system using newly developed methods from the literature (MPSI-LOPCOW-BSS) in an integrated framework. The results obtained by the two criteria weighting methods are combined using a combination operator to increase reliability. In addition, sensitivity analysis is performed to demonstrate the robustness of the proposed decision support system.

The remainder of this article is structured as follows: Section 1 (Introduction) presents the theoretical background and literature review. Section 2 describes the MPSI-LOPCOW-BSS method and outlines the research methodology. Section 3 applies performance analyses to the Visegrad countries. Section 4 discusses the research findings, key insights, sensitivity analysis. Finally, Section 5 concludes the study with final evaluations.

## 2. LITERATURE REVIEW

The level of information technology has been addressed in the literature using various methods across different fields. A literature review on Information and Communication Technology (ICT) reveals that the relationship between ICT levels and economic growth is a frequently studied topic (Yaprakli & Sağlam, 2010; Artan et al., 2014; Albiman & Sulong, 2017; Özkan & Çelik, 2018; Fernández-Portillo et al., 2020; Cheng et al., 2021).

Additionally, studies have been published addressing topics such as the relationship between ICT and development (Jin & Cho, 2015), the effects of ICT on carbon emissions (Wang et al., 2024), the impact of ICT use on PISA performance (Goh et al., 2024), and the relationship between ICT and financial development (Samargandi et al., 2019; Cheng et al., 2021). These studies have employed methods such as panel data analysis, ARDL, Granger causality analysis, regression analysis, and principal component analysis.

Some studies address ICT levels using multi-criteria decision-making methods (Setiawan et al., 2016; Merkevičius & Yadav, 2019; Yakut, 2020; Ersoy, 2021; Torkayesh & Torkayesh, 2021; Ecemiş & Çoşkun, 2022; Demir, 2022; Keleş, 2024; Ecer & Güneş, 2024; Macit, 2024).

In general, methods such as AHP, TOPSIS, MEREC, CRITIC, LBWA, MPSI and MARCOS have been used in the studies. In addition to these studies, research utilizing fuzzy sets has been conducted. Bahnamiri et al. (2015) employed fuzzy entropy and TOPSIS methods, Karabasevic et al. (2021) used fuzzy MULTIMOORA, and Nasri et al. (2022) applied fuzzy AHP-VIKOR methods. Typically, criteria are weighted using a single method. Demir (2022) applied PSI-LOPCOW methods, calculating the final weights through a Bayesian aggregation operator. In the study by Ecer & Güneş (2024), MEREC and CRITIC methods were used, and the final criterion weight was determined using an aggregation operator proposed by Torkayesh et al. (2021). Both studies recommended the use of "different methods" for future research. This study complies with this recommendation by using a different aggregation operator. Additionally, a novel integrated decision support system is proposed, unlike those in previous studies.

Although the MPSI method is relatively new, it is widely used in the literature. Gligorić et al. (2022) integrated the MPSI method with the MARA method to help engineers in the mining sector select appropriate support methods. In his study, Yılmaz (2023) used the MPSI-MARA methods in an integrated manner to determine the financial performances of banks. Akbulut & Aydın (2024) examined the multidimensional sustainability performances of deposit banks using the MPSI, MSD, and RAWEC methods. In their study, Torres et al. (2024) propose an integrated decision support system consisting of the MPSI-SPOTIS methods for the selection of unmanned aerial vehicles. Ersoy et al. (2025) employed the MPSI-RAPS model to determine the progress of EU countries in achieving the Sustainable Development Goals (SDGs). Wittig Vienna et al. (2025) proposed a hybrid ranking methodology consisting of MPSI and CoCoSo methods to assess efforts toward renewable energy transition among OECD member countries. Kara et al. (2025) utilized the MPSI-OPLO-POCOD method to determine the ESG-based sustainability performance levels of 17 software companies listed in the S&P 500 index for the years 2021, 2020, 2019, and 2018.

The LOPCOW method has been applied in various fields in the literature. Ulutaş et al. (2023) used an integrated MCDM model consisting of MEREC, LOPCOW, and MCRAT methods for the natural fiber selection problem in building insulation materials. In their research, Öztaş & Öztaş (2024) apply the LOPCOW method in conjunction with the MAIRCA method to evaluate the innovation performances of G20 countries. Dündar (2024) examined the performance of 200 state and foundation universities operating in Turkey in terms of project submission and execution capacities within the scope of the Research Support Programs Directorate (ARDEB) using the LOPCOW-CRADIS methods. In their study, Dhruva et al. (2025) address the selection of the "Food Waste Treatment Method" (FWTM). The study utilizes q-Rung Orthopair Fuzzy Set and proposes an MCDM framework consisting of LP-LOPCOW-COPRAS methods. Altıntaş (2025) utilizes the most up-to-date data from the Global Food Security Index (GFSI) for 2022 to evaluate the food security performances of G7 countries using the Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) based Double Normalization-Based Multiple Aggregation (DNMA) Multi-Criteria Decision-Making (MCDM) method. Setiawansyah et al. (2025) used the LOPCOW method in conjunction with the AROMAN method for the store selection problem.

The BSS method is a new approach. It has been utilized in two studies developed by Bulut (2024a). In Bulut's (2024a) work, it was applied to measure the capacity of the Turkish Health System, while in Bulut (2024b), it was used in another context. In his research, Bağcı (2025) ranked various countries according to the importance levels of digital finance indicators. This study employed the NMV-BSS methods.

In the existing literature, most studies on Information and Communication Technologies (ICT) have overlooked the MPSI-LOPCOW-BSS methods, particularly in the context of the Visegrad countries. This gap is notable, especially given the economic integration of these countries and their role in the EU digital agenda. Assessing ICT levels using a novel integrated framework not only advances methodological approaches but also holds significant policy relevance. Furthermore, the literature predominantly employs a single weighting method, which emphasizes the need for studies that integrate various methods and multi-criteria decision-making processes. To address this gap, the present research proposes an integrated decision support system utilizing the MPSI-LOPCOW-BSS methods, focusing on the Visegrad countries as a case study. This approach is crucial for evaluating the effects of different weighting methods and for assessing ICT performance specifically within this region.

## 3. METHODOLOGY

In this section of the study, the steps of the proposed integrated MPSI-LOPCOW-BSS method will be outlined. The criteria identified through a literature review related to the specified topic have been weighted separately using the MPSI and LOPCOW methods. Subsequently, the final criterion weight was obtained using a combination operator found in the literature, and the problem was solved using the BSS method. The process related to the solution is shown in Figure 1.

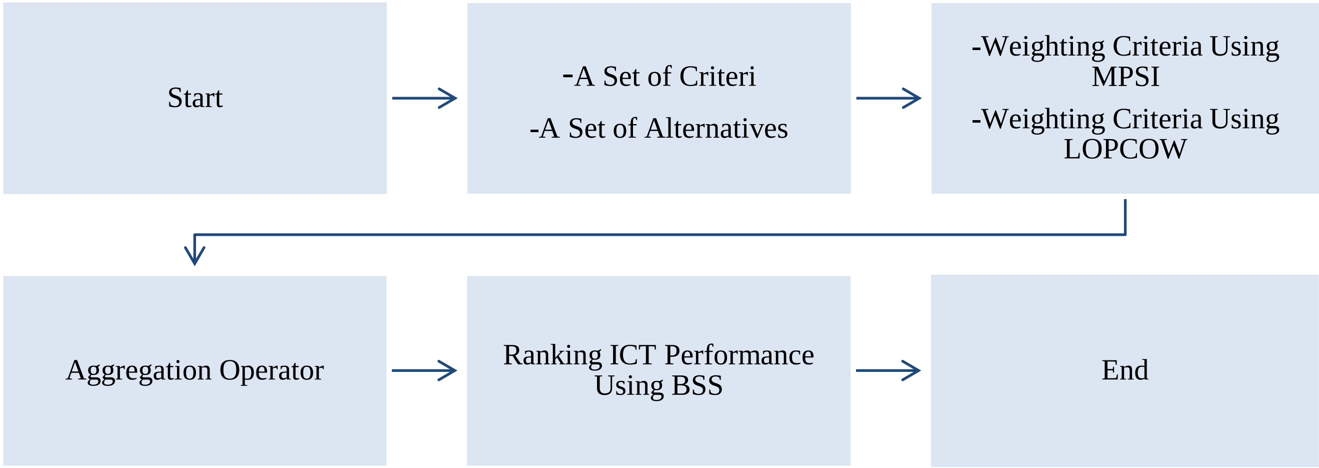


**Figure 1.** The Structural Foundation of Methodology

### 3.1. MPSI

The MPSI (Modified Preference Selection Index) method focuses on the fluctuations in preference values of criteria, reflecting the differences between normalized values and the average Euclidean distance (Macit, 2024). This method offers a simple and efficient way to determine the objective weights of criteria. Additionally, the computation of weight coefficients using this newly developed technique is not overly complex, which enhances the MPSI's potential as a widely applicable problem-solving tool. This approach builds upon the PSI method, resulting in an improved version known as the MPSI. The MPSI modifies PSI by removing a single step, thereby increasing the accuracy of weight coefficients. This slight change enhances the accuracy of the final weight coefficient values, aligning them more closely with those generated by other objective weighting methods (Gligorić et al., 2022). The new approach has the following steps (Gligorić et al., 2022; Kara et al., 2025).

***Step 1.1. Decision matrix:*** To calculate the criteria weighing, the initial decision matrix must first be constructed. In the initial decision matrix, the values for each alternative are determined based on the criteria.

***Step 1.2. Creating the normalized decision matrix:***

$$r_{ij} = \frac{x_{ij}}{maxx_{ij}} \quad i = 1,2,\dots,m \quad \text{for benefit-oriented criteria} \tag{1}$$

$$r_{ij} = \frac{minx_{ij}}{x_{ij}} \quad i = 1,2,\dots,m \text{ for cost-oriented criteria} \tag{2}$$

***Step 1.3. Calculate the mean value $v_j$ of the normalized evaluations of criterion $j$ and it is calculated with the following equation:***

$$v_j = \frac{1}{m}\sum_{i=1}^{m} r_{ij} \tag{3}$$

***Step 1.4. Calculate the preference variation value $p_j$ as follows:***

$$p_j = \frac{1}{m}\sum_{i=1}^{m}(r_{ij-v_j})^2 \tag{4}$$

***Step 1.5. The criteria weights $w_j$ are determined using the following equation:***

$$w_j = \frac{p_j}{\sum_{j=1}^{n} p_j} \tag{5}$$

### 3.2. LOPCOW

The LOPCOW method is a criterion weighting approach developed by Ecer and Pamucar in 2022. As an objective method, it establishes criterion weights independently of decision-makers' opinions. A key aspect of this method is its consideration of negative performance values among alternatives, which aids in accurately determining criterion weights and facilitates the effective analysis of numerous criteria and alternatives (Biswas et al., 2022). The LOPCOW method employs a logarithmic function to calculate the standard deviation for each criterion based on the number of alternatives, resulting in percentage values that more accurately reflect the differences between more and less significant criteria.

The method consists of three steps. First, an internal decision matrix is created, consisting of *m* alternatives and *n* criteria, to identify and solve the decision problem.

***Step 2.1. Creating the normalized decision matrix:***

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \text{ for benefit-oriented criteria} \quad (6)$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \text{ for cost-oriented criteria} \quad (7)$$

***Step 2.2. Creating the $PV_{ij}$ matrix of percentage values for each criterion***

$$PV_{ij} = \left| ln\left(\frac{\sqrt{\sum_{i=1}^{m} r_{ij}^2/m}}{\sigma}\right)100 \right| \quad (8)$$

***Step 2.3. Calculating objective weights ($W_j$)***

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \quad (9)$$

### 3.3. BSS (Bulut Scoring Systems)

The studies published by Bulut (2024) have contributed to the literature and introduced a ranking method that is used in various fields.

***Step 3.1. Building the decision matrix:*** As with other MCDM methods, the decision matrix is first created. The columns of the decision matrix represent the decision criteria, while the rows represent the decision alternatives.

***Step 3.2. Calculation of unstandardized raw scores:*** This step involves first determining the weights of the decision criteria using any method. The BSS uses the determined weights of the decision criteria as input. Here, $w_j$ Denotes the weights of the decision criteria. Initially, Equation (10) calculates the unstandardized raw value matrix (V) from the decision matrix. Equation (10) is applied to each row in the decision matrix to produce a new matrix of size a*c similar to the decision matrix. This matrix is called the V matrix. Equation (11) then calculates the unstandardized raw scores (R) of each alternative from the V matrix.

$$V = o_1 * w_1 * x_1 + o_2 * w_2 * x_2 + o_3 * w_3 * x_3 + \ldots + o_j * w_j * x_j \quad (10)$$

$$R = \frac{V}{a*c} \text{ where } c>1 \text{ and } a>1 \quad (11)$$

***Step 3.3. Calculation of band value:*** After calculating the non-standardized raw scores (R) of the alternatives, the maximum and minimum scores within the raw scores are determined, and their absolute values are taken and summed. This process ensures that the non-standardized raw scores are 0 and above. This process is given in the equation below. At this stage, the direction of the criteria is determined according to the benefit and cost criteria of the decision criteria, in other words, according to the optimality criteria of the decision criteria. If the decision criterion requires cost, the direction of the decision criterion is determined as minimum, and if it requires a benefit criterion, it is determined as maximum.

$$M = \left|R_j^{max}\right| + \left|R_j^{min}\right| \quad (12)$$

***Step 3.4. Calculation of BSS scores:*** The BPS scores of the decision alternatives are calculated using equation (13). The reason for using the natural logarithm (ln) in the equation is to standardize the scores obtained. Since ln(0) = "undefined", +1 is added to the equation. Thus, the scores obtained are evaluated at 0 and above.

$$BSS = ln(R + M + 1) \quad (13)$$

### 3.4. Aggregation Operator

It is not unexpected that the weights obtained using different MCDM methods vary from one another. Therefore, a weight aggregation operator can be used to derive an optimal weight from these different weights. In this study, the aggregation operator provided in Equation (14) is utilized (Ecer & Güneş, 2024; Torkayesh et al., 2021).

$$w_{FİNAL} = \Gamma.\, w_{MPSI} + (1 - \Gamma).\, w_{LOBCOW} \quad (14)$$

In Equation (14), Γ is the aggregation coefficient, and it is recommended to use Γ = 0.5 (Ecer & Güneş, 2024).

## 4. PROBLEM DEFINITION and CASE STUDY

This section presents the proposed integrated MCDM approach for evaluating the ICT development performance of the Visegrad countries, considering economic and social development pillars. First, nine main criteria obtained through a literature review are explained. To obtain realistic and applicable results, real data from OECD datasets for these countries are used. Subsequently, the MPSI, LOPCOW, and BSS methods are used to calculate the relative importance of the indicators and the performance of the countries.

### 4.1. Identification of Indicators

Various criteria are used in the literature to measure the level of ICT. In the studies of (Ecer & Güneş, 2024; Torkayesh & Torkayesh, 2021), 6 main criteria were used to determine the level of ICT. Unlike these studies, the number of criteria has been increased to 9. All criteria are benefit-oriented. Data on these criteria were obtained from the OECD data bank. The shared data varies between 2017-2024. Therefore, the most recently shared data was taken into account. The variables considered as criteria in the decision model are defined as follows:

***ICT Value Added ($C_1$):*** ICT value added refers to the difference between the gross output of the ICT sector and its intermediate consumption, expressed as a percentage of gross value added.

***ICT Employment ($C_2$):*** ICT employment is defined as the number of individuals working within the ICT sector, represented as a percentage of total employment in the sector.

***ICT Investment ($C_3$):*** ICT investment encompasses the purchase of equipment and software that have been utilized in production for over a year.

***ICT Goods ($C_4$):*** Exports of ICT goods are categorized according to the World Customs Organization Harmonised System (HS), which identifies various ICT products, including ICT goods.

***Home Computer Access ($C_5$):*** This metric represents the number of households that possess at least one computer.

***Internet Access in households ($C_6$):*** This percentage indicates the proportion of households that report having internet access, defined as those stating they have connectivity to the internet.

***Mobile Broadband - per 100 inhabitants ($C_7$):*** Refers to the number of mobile broadband subscriptions per 100 inhabitants. This indicates the access rate to mobile internet services.

***Fixed Broadband – per 100 inhabitants ($C_8$):*** Indicates the number of fixed broadband subscriptions per 100 inhabitants. This measures the prevalence of fixed-line internet services.

***Mobile Data Usage – gigabits per subscription per month ($C_9$):*** Represents the monthly mobile data usage per subscription in gigabits. This shows the amount of mobile data consumption.

### 4.2. Information about the Visegrad Countries

The Visegrad Group, often referred to as the Visegrad Four or V4, is a cultural and political alliance comprising four Central European nations: Czechia, Hungary, Poland, and Slovakia. This coalition seeks to enhance collaboration in areas such as military, economic, cultural, and energy matters. Additionally, all four countries are members of the European Union, the North Atlantic Treaty Organization, and the Three Seas Initiative.

The group takes its name "Visegrad" from the city of the same name in Hungary (Visegrad). Although the group's history dates back a long time, it stands out as one of the oldest economic and political collaborations. It was first convened in 1335 in the town of Visegrad, hosted by Hungarian King Charles I. The other participants of the meeting, known as the "Visegrad Congress," were King John of Bohemia and King Casimir III of Poland. The meeting was held to resolve interstate issues, ensure security, cooperate, and improve friendship (Visegrad). Thanks to this meeting, on which the foundations of today's Visegrad Group are based, they have generally followed a coordinated policy to this day (Yeşiltaş & Erdem, 2021).

**Table 1.** Profile of Visegrad Countries

| Country | GDP (current US$) | GDP per capita | Population |
|---|---|---|---|
| Czechia | 343.21 | 31,591.2 | 10.864.042 |
| Hungary | 212.39 | 22,141.9 | 9.592.186 |
| Poland | 809.2 | 22,056.7 | 36.687.353 |
| Slovakia | 132.91 | 24,491.38 | 5.426.740 |

**Source:** World Bank, 2023.

As shown in Table 1, Czechia stands out in terms of economic welfare with the highest GDP per capita. Slovakia also has a high GDP per capita, but its total economic size is lower. Poland leads in total GDP, yet its GDP per capita lags behind that of the other countries. Hungary has a similar GDP per capita to Poland but has a lower total GDP, indicating a balance that highlights important considerations for economic development.

## 5. RESULTS

The dataset used in the study is shown in Table 2. All the criteria in the study are benefit-oriented criteria. In Table 2, the alternatives are listed in the rows, while the criteria are presented in the columns.

**Table 2.** Dataset

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **Country Code** | **Max** | **Max** | **Max** | **Max** | **Max** | **Max** | **Max** | **Max** | **Max** |
| Czechia-A1 | 4,9 | 3,7 | 4,32 | 16,1 | 82,18 | 94,56 | 107,22 | 38,19 | 9,89 |
| Hungary-A2 | 5,5 | 4 | 1,73 | 10,3 | 79,67 | 94,78 | 88,36 | 37,05 | 13,89 |
| Poland-A3 | 4 | 3,2 | 0,8 | 6,5 | 81,78 | 95,89 | 135,55 | 25,17 | 14,94 |
| Slovakia-A4 | 4,5 | 3,7 | 1,4 | 10,5 | 81,80 | 90,54 | 94,41 | 33,10 | 11,89 |

**Source:** OECD, Eurostat, World Bank.

### 5.1. MPSI Results

Equations 1 and 2 have been used to normalize the decision matrix presented in Table 2. The normalized decision matrix is shown in Table 3.

**Table 3.** The Normalized Initial Decision-Making Matrix

| Country Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **A1** | 0,8909 | 0,925 | 1 | 1 | 1 | 0,986 | 0,791 | 1 | 0,6619 |
| **A2** | 1 | 1 | 0,4004 | 0,6397 | 0,9694 | 0,9884 | 0,6518 | 0,9701 | 0,9297 |
| **A3** | 0,7272 | 0,8 | 0,1851 | 0,40372 | 0,9951 | 1 | 1 | 0,6590 | 1 |
| **A4** | 0,8181 | 0,925 | 0,3240 | 0,6521 | 0,9953 | 0,9442 | 0,6964 | 0,8667 | 0,7958 |

Values of $v_j, p_j, and\ w_j$ have been calculated using Equations 3, 4, and 5. These values are shown in Table 4.

**Table 4.** The $v_j, p_j, and\ w_j$ values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $v_j$ | 0,8590 | 0,9125 | 0,4774 | 0,6739 | 0,9899 | 0,9796 | 0,7848 | 0,8739 | 0,8468 |
| $p_j$ | 0,0399 | 0,0206 | 0,3879 | 0,1809 | 0,0005 | 0,0017 | 0,0718 | 0,0713 | 0,0671 |
| $w_j$ | 0,0474 | 0,0244 | 0,4606 | 0,2149 | 0,0006 | 0,0021 | 0,0852 | 0,0847 | 0,0796 |
| **Ranking** | 7 | 6 | 1 | 2 | 9 | 8 | 3 | 4 | 5 |

### 5.2. LOPCOW Results

The decision matrix provided in Table 1 has been used. Since all criteria are maximized, the decision matrix has been normalized using Equation 2. This is shown in Table 5.

**Table 5.** Normalized Decision Matrix

| Country Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,6 | 0,6250 | 1 | 1 | 1 | 0,7514 | 0,3996 | 1 | 0 |
| A2 | 1 | 1 | 0,2642 | 0,3958 | 0 | 0,7925 | 0 | 0,9124 | 0,7920 |
| A3 | 0 | 0 | 0 | 0 | 0,8406 | 1 | 1 | 0 | 1 |
| A4 | 0,3333 | 0,6250 | 0,1704 | 0,4166 | 0,8486 | 0 | 0,1282 | 0,6090 | 0,3960 |

Subsequently, the percentage values and the weight values of the criteria have been calculated using Equations 4 and 5. These are shown in Table 6.

**Table 6.** $PV_{ij}, w_j$ Values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $PV_{ij}$ | 42,14 | 51,70 | 27,55 | 37,11 | 67,1 | 62,09 | 30,95 | 62,34 | 51,79 |
| $w_j$ | 0,0973 | 0,1194 | 0,0636 | 0,0857 | 0,1551 | 0,1434 | 0,0715 | 0,1440 | 0,1196 |

### 5.3. Aggregation Operator

The calculation made using Equation 14 has resulted in the final W value shown in Table 7.

**Table 7.** $W_{last}$ Values

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $W_{MPSI}$ | 0,0474 | 0,0244 | 0,4606 | 0,2149 | 0,0006 | 0,0021 | 0,0852 | 0,0847 | 0,0796 |
| $W_{LOBCOW}$ | 0,0973 | 0,1194 | 0,0636 | 0,0857 | 0,1551 | 0,1434 | 0,0715 | 0,1440 | 0,1196 |
| $W_{last}$ | 0,0723 | 0,0719 | 0,2621 | 0,1503 | 0,0779 | 0,0727 | 0,0783 | 0,1143 | 0,0996 |

As shown in the table, the criterion with the highest final weight is $C_3$ (ICT Investment). Figure 3 displays the results related to MPSI, LOPCOW, and the final weights.

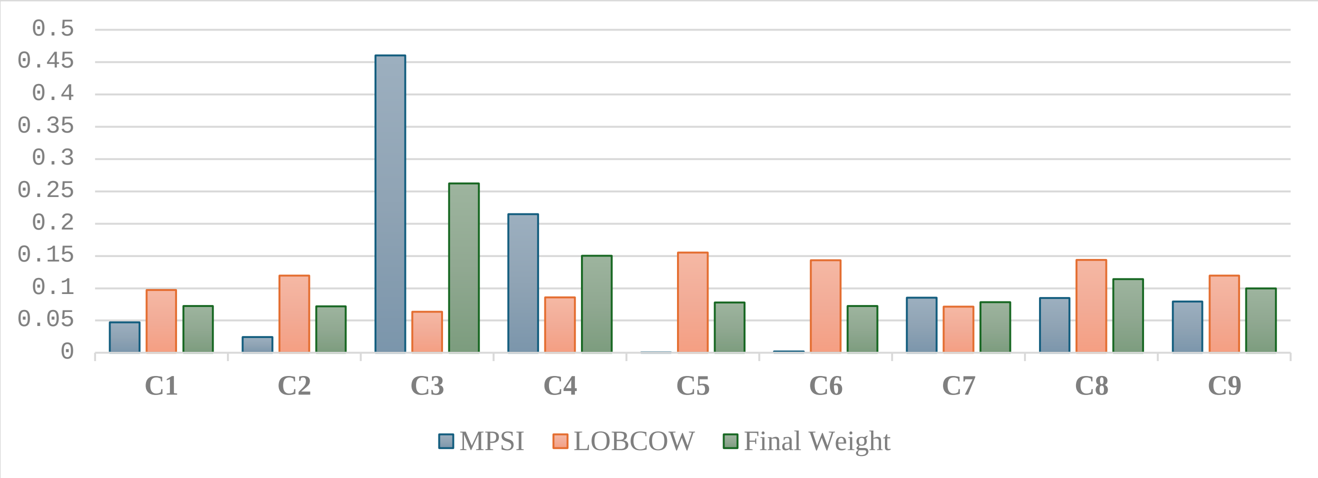


**Figure 2.** Criterion Weights

### 5.4. BSS Results

The decision matrix used in the study is shown in Table 1. Additionally, the criterion weights used in the BSS calculations are provided in Table 7. The decision matrix has been normalized using Equation 10.

**Table 8.** Standardized Decision Matrix

| Country Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,3547 | 0,2663 | 1,1325 | 2,4202 | 6,4042 | 6,883 | 8,4058 | 4,3684 | 0,9857 |
| A2 | 0,3981 | 0,2879 | 0,4535 | 1,5483 | 6,2086 | 6,899 | 6,9272 | 4,238 | 1,3843 |
| A3 | 0,2895 | 0,2303 | 0,2097 | 0,9771 | 6,373 | 6,9798 | 10,6268 | 2,8791 | 1,489 |
| A4 | 0,3257 | 0,2663 | 0,367 | 1,5784 | 6,3746 | 6,5904 | 7,4016 | 3,7862 | 1,185 |

The R value has been calculated using Equation 11, the M value using Equation 12, and the BSS value using Equation 13, as shown in Table 9.

**Table 9.** BSS Scores

| Alternatives | R | BSS | M | Rank |
|---|---|---|---|---|
| A1 | 0,8672 | 1,2553 | 1,6416 | 1 |
| A2 | 0,7874 | 1,2322 | 1,6416 | 3 |
| A3 | 0,8348 | 1,246 | 1,6416 | 2 |
| A4 | 0,7743 | 1,2284 | 1,6416 | 4 |

The alternatives are ranked according to the Bulut Scoring System (BSS) values. BSS values represent the performance of alternatives, where a higher BSS value indicates better performance.

### 4.5. Sensitivity Analysis

In this study, the aggregation coefficient value was taken as Γ = 0.5, and the results of the research were obtained. To test the robustness of the model, this coefficient was considered as different values between 0.1 and 0.9, and the rankings were determined.

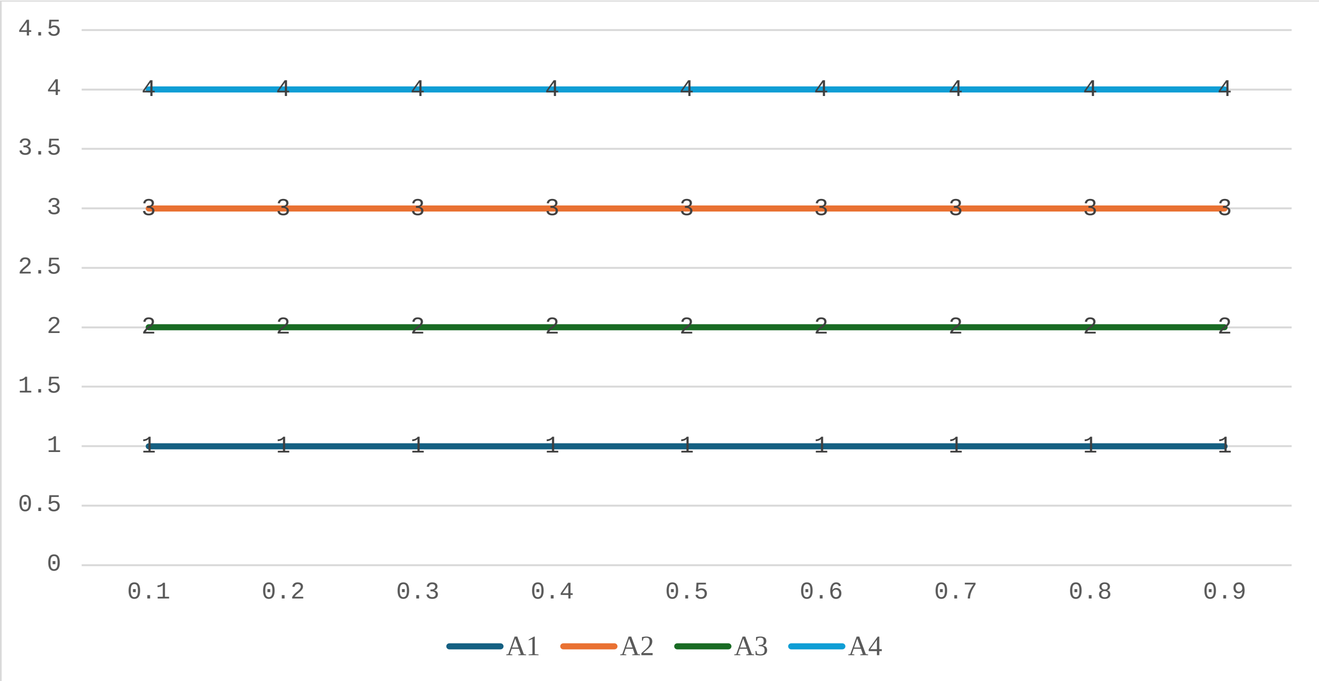


**Figure 3.** Alternative Rankings for Different Merging Coefficient Values

According to Figure 3, the positions of all alternatives are the same across all scenarios. These results demonstrate the robustness of the model.

### 4.6. Comparative Analysis

The proposed decision support system is compared using different ranking methods. The problem was solved using the criterion weights obtained from the MPSI-LOPCOW methods along with the EDAS, OCRA, WASPAS, and GRA methods. The results regarding these methods are presented in Table 10.

**Table 10.** Comparative Analysis

| Alternatives | BSS | EDAS | OCRA | GRA | WASPAS |
|---|---|---|---|---|---|
| A1 | 1 | 1 | 1 | 1 | 1 |
| A2 | 3 | 2 | 3 | 2 | 3 |
| A3 | 2 | 4 | 2 | 4 | 2 |
| A4 | 4 | 3 | 4 | 3 | 4 |

The obtained results were compared statistically using the Spearman Rank Correlation Coefficient test. The results of the analysis are presented in Table 11.

**Table 11.** Results of the Spearman Rank Correlation Coefficient Test

| Correlations | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | **BSS** | **EDAS** | **OCRA** | **GRA** | **WASPAS** |
| **Spearman's rho** | **BSS** | Correlation Coefficient | 1,000 | ,400 | 1,000** | ,400 | 1,000** |
| | | Sig. (2-tailed) | . | ,600 | . | ,600 | . |
| | | N | 4 | 4 | 4 | 4 | 4 |
| | **EDAS** | Correlation Coefficient | ,400 | 1,000 | ,400 | 1,000** | ,400 |
| | | Sig. (2-tailed) | ,600 | . | ,600 | . | ,600 |
| | | N | 4 | 4 | 4 | 4 | 4 |
| | **OCRA** | Correlation Coefficient | 1,000** | ,400 | 1,000 | ,400 | 1,000** |
| | | Sig. (2-tailed) | . | ,600 | . | ,600 | . |
| | | N | 4 | 4 | 4 | 4 | 4 |
| | **GRA** | Correlation Coefficient | ,400 | 1,000** | ,400 | 1,000 | ,400 |
| | | Sig. (2-tailed) | ,600 | . | ,600 | . | ,600 |
| | | N | 4 | 4 | 4 | 4 | 4 |
| | **WASPAS** | Correlation Coefficient | 1,000** | ,400 | 1,000** | ,400 | 1,000 |
| | | Sig. (2-tailed) | . | ,600 | . | ,600 | . |
| | | N | 4 | 4 | 4 | 4 | 4 |

**Note:** ** Correlation is significant at the 0.01 level (2-tailed).

There are perfect positive correlations between the rankings of BSS and OCRA, BSS and WASPAS, EDAS and GRA, as well as OCRA and WASPAS; this indicates that the rankings among these methods are identical. Some pairs, such as BSS with EDAS and GRA, and EDAS with OCRA and WASPAS, show moderate correlations, but these are not statistically significant.

## 6. CONCLUSION

The levels of information and communication technologies are highly important for international competition. As seen in the literature, there is a positive relationship between the levels of information and communication technologies and economic growth, development, etc.

Determining the information and communication technology levels of the Visegrad countries is important in terms of revealing the situation of the countries. In this study, the Visegrad countries were evaluated with various criteria using OECD data. For this purpose, a model was developed by integrating MPSI-LOPCOW-BSS methods, which are among the MCDM methods. In the model, two different objective criteria weighting methods were used. The results obtained from these two methods were used to obtain the final criteria weights with the help of a merging operator. Afterward, the final criteria weights found were used in the BSS method to reach the ICT development performances of the V4 countries.

In the weighting conducted using the MPSI method, the $\mathrm{C}_3$-ICT Investment criterion was found to have the highest weight. In the LOPCOW method, the $\mathrm{C}_5$-Home Computer Access criterion holds the highest weight. After using the aggregation operator, the highest weight among the criteria was again assigned to the $\mathrm{C}_3$-ICT Investment criterion. Subsequently, the $\mathrm{C}_4$-ICT Goods and $\mathrm{C}_8$-Fixed Broadband criteria were identified as having high weights. The criterion with the lowest weight was $\mathrm{C}_2$-ICT Employment. In the literature, different results have been found. Ecer & Güneş (2024) identified the export of ICT products as the criterion with the highest weight in their study. In the study by Torkayesh & Torkayesh (2021), ICT employment was also identified as the criterion with the highest weight. This discrepancy arises from both differences in sample selection and the varying number of total criteria used. In the ranking conducted using the BSS method, the country with the highest ICT level was Czechia. It was followed by Poland, Hungary, and Slovakia. To strengthen the implications of these findings, it is essential to delve deeper into the political and strategic effects of the results. The high weighting of the $C_3$-ICT Investment criterion suggests that investment in ICT infrastructure is crucial for enhancing the competitive standing of the Visegrad countries in the global market. Policymakers should focus on allocating resources to ICT investments as a means to stimulate economic growth and improve overall development. Furthermore, the significant weight assigned to the $C_5$-Home Computer Access criterion indicates the importance of digital inclusion in fostering a technologically adept society. Strategies aimed at increasing access to home computing can facilitate skill development and enhance productivity, ultimately contributing to economic advancement. Given the findings, it is recommended that V4 countries adopt coordinated policies that prioritize ICT investments and promote accessibility to technology. Collaborative initiatives, such as public-private partnerships, can be effective in maximizing the impact of ICT on economic growth.

Based on the findings, countries, especially Slovakia, which ranks lowest among the Visegrad countries, need to focus on various criteria in accordance with the Digital Agenda for Europe 2030 policies:

- Visegrad countries should increase their investments in ICT infrastructure. This will help enhance their global competitiveness. Specifically, the high weight of the $C_3$-ICT Investment criterion indicates how critical investments in this area are.
- Based on the importance of criteria such as home computer access ($C_5$) and internet access ($C_6$), strategies should be developed to enhance digital inclusion. Governments should create programs to ensure access to digital tools for disadvantaged groups.
- Educational programs and workshops should be organized to improve digital literacy. This will enhance individual competencies and contribute to the growth of the digital economy.
- Policies should be developed to promote public-private partnerships that accelerate ICT investments. Such partnerships can ensure the effective use of resources.
- To enhance competitiveness in Europe's digital market, the standardization of data and digital services is necessary. This will facilitate cross-border data flow and make business operations more efficient.

These recommendations will help Visegrad countries develop important policies to support their digital transformation processes and align with the EU's digital goals for 2030.

The contribution of the study to the literature has been twofold. First, the results were presented consistently with the integrated model proposed in the study. Secondly, the concrete situations of the countries were determined by revealing the ICT development performances of the Visegrad countries.

Limitation:

- The research is limited to Visegrad countries only.
- The research uses only quantitative data; subjective methods or fuzzy set-based methods can be used.

There are various implications for future studies. The first is the use of different MCDM methods. The second is to reveal the effects on the results by using different merging operators, and the third is to determine the levels of different country groups.

**AUTHORS' DECLARATION:**

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

**AUTHORS' CONTRIBUTIONS:**

The entire research is written by the author.

## REFERENCES

Akbulut, O. Y., & Aydın, Y. (2024). A hybrid multidimensional performance measurement model using the MSD-MPSI-RAWEC model for Turkish banks. *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty*, *11*(3), 1157-1183. https://doi.org/10.30798/makuiibf.1464469

Albiman, M. M., & Sulong, Z. (2017). The linear and non-linear impacts of ICT on economic growth, of disaggregate income groups within SSA region. *Telecommunications Policy*, *41*(7-8), 555-572. https://doi.org/10.1016/j.telpol.2017.07.007

Altıntaş, F. F. (2025). Analysis of food security performances of G7 countries: An application with LOPCOW-based DNMA method. *ITU Journal of Food Science and Technology*, *3*(1), 27-42. Available at: https://dergipark.org.tr/en/download/article-file/4168546

Artan, S., Hayaloğlu, P., & Baltacı, N. (2014). Bilgi ve iletişim teknolojilerindeki gelişmelerin iktisadi büyüme üzerindeki etkisi: Geçiş ekonomileri örneği. *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi*, *28*(1), 199-214. https://doi.org/10.16951/iibd.40642

Bağcı, H. (2025). The importance of digital finance indicators and comparison of digital finance performance using Bulut Scoring System. *JOEEP: Journal of Emerging Economies and Policy*, *10*(1), 432-449. Available at: https://dergipark.org.tr/en/download/article-file/4337142

Bahnamiri, M. V., Khademabbasi, S., & Valinataj, M. (2015). A multi-criteria decision method using fuzzy TOPSIS technique for ranking countries based on ICT development index (IDI). *International Journal of Applied Business and Economic Research*, *13*(6), 3851-3869.

Batbaylı, Ş. (2024). Uluslararası ticarette bilgi ve iletişim teknolojileri sektörünün rekabet gücü vet G-8 ülkeleri üzerine karşılaştırmalı bir analiz. *Studies on Social Science Insights*, *4*(1), 27-46. http://dx.doi.org/10.53035/SOSSCI.76

Biswas, S., Bandyopadhyay, G., & Mukhopadhyaya, J. N. (2022). A multi-criteria framework for comparing dividend pay capabilities: Evidence from Indian FMCG and consumer durable sector. *Decision Making: Applications in Management and Engineering*, *5*(2), 140-175. https://doi.org/10.31181/dmame0306102022b

Bulut, T. (2024a). A new quantitative method proposal for evaluation of Turkish health system capacity: Bulut Scoring System (BSS). *6th International Black Sea Modern Scientific Research Congress, Trabzon, 23-25 August 2024 (Session III, Part 1).* https://doi.org/10.5281/zenodo.13871545

Bulut, T. (2024b). Bulut Scoring System. In Ş. Yücel, & R. Yücel (Eds.), *Nicel karar yöntemleri alanında uluslararası araştırmalar-I* (pp. 1-18). Eğitim Yayınevi. https://doi.org/10.5281/zenodo.13970751

Chen, C. L., Lin, Y. C., Chen, W. H., Chao, C. F., & Pandia, H. (2021). Role of government to enhance digital transformation in small service business. *Sustainability*, *13*(3), 1028. https://doi.org/10.3390/su13031028

Cheng, C. Y., Chien, M. S., & Lee, C. C. (2021). ICT diffusion, financial development, and economic growth: An international cross-country analysis. *Economic Modelling*, *94*, 662-671. https://doi.org/10.1016/j.econmod.2020.02.008

Demir, G. (2022). Bilgi ve iletişim teknolojisinin G8 ülkelerindeki gelişiminin değerlendirilmesi. *Journal of Business and Communication Studies*, *1*(2), 165-178. http://dx.doi.org/10.29228/jobacs.67424

Dhruva, S., Krishankumar, R., Ravichandran, K. S., Kaklauskas, A., Zavadskas, E. K., & Gupta, P. (2025). Selection of waste treatment methods for food sources: An integrated decision model using q-rung fuzzy data, LOPCOW, and COPRAS techniques. *Clean Technologies and Environmental Policy*, 1-25. https://doi.org/10.1007/s10098-025-03160-6

Dündar, S. (2024). Project performance analysis of Turkish universities by LOPCOW-CRADIS methods. *Journal of Turkish Operations Management*, *8*(2), 409-425. https://doi.org/10.56554/jtom.1336202

Ecemiş, O., & Coşkun, A. (2022). Türkiye'de bilişim teknolojileri kullanımının ÇKKV yöntemleriyle incelenmesi 2014-2021 dönemi. *Avrupa Bilim ve Teknoloji Dergisi*, (37), 81-89. https://doi.org/10.31590/ejosat.1134753

Ecer, F., & Güneş, E. (2024). G7 ülkelerinin bilgi iletişim teknoloji düzeylerini belirleme: MEREC-CRITIC entegre ağırlıklı CoCoSo metodolojisi. *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty*, *11*(1), 219-242. https://doi.org/10.30798/makuiibf.1281607

Ecer, F., & Pamucar, D. (2022). A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: An application in developing country banking sector. *Omega*, (112), 102690. https://doi.org/10.1016/j.omega.2022.102690

Ersoy, N. (2022). Comparative analysis of MCDM methods for the assessment of ICT development in G7 countries. *Kafkas Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 13*(25), 55-73. https://doi.org/10.36543/kauiibfd.2022.003

Ersoy, N., Özçalıcı, M., & Trung, D. D. (2025). A hybrid MCDM approach for SDGs assessment of EU countries. *Spectrum of Decision Making and Applications*, *3*(1), 164-186. https://doi.org/10.31181/sdmap31202637

Fernández-Portillo, A., Almodóvar-González, M., & Hernández-Mogollón, R. (2020). Impact of ICT development on economic growth. A study of OECD European union countries. *Technology in Society*, *63*, 101420. https://doi.org/10.1016/j.techsoc.2020.101420

Gligorić, M., Gligorić, Z., Lutovac, S., Negovanović, M., & Langović, Z. (2022). Novel hybrid MPSI-MARA decision-making model for support system selection in an underground mine. *Systems*, *10*(6), 248. https://doi.org/10.3390/systems10060248

Goh, T. T., Yang, B., Yan, Y., & Liu, M. (2024). The complex influence of information communication technology (ICT) on students' performance in Singapore: Evidence from 2018 PISA data. *Computers in the Schools*, 1-21. https://doi.org/10.1080/07380569.2024.2344022

Harris, I., Wang, Y., & Wang, H. (2015). ICT in multimodal transport and technological trends: Unleashing potential for the future. *International Journal of Production Economics*, *159*, 88-103. https://doi.org/10.1016/j.ijpe.2014.09.005

Heeks, R. (2010). Do information and communication technologies (ICTs) contribute to development?. *Journal of International Development*, *22*(5), 625-640. https://doi.org/10.1002/jid.1716

Jin, S., & Cho, C. M. (2015). Is ICT a new essential for national economic growth in an information society?. *Government Information Quarterly*, *32*(3), 253-260. https://doi.org/10.1016/j.giq.2015.04.007

Kara, K., Özyürek, H., & Yalçın, G. C. (2025). Evaluating ESG-based sustainability in software companies: A performance analysis using MPSI-OPLO-POCOD framework. *Computer and Decision Making: An International Journal*, *2*, 570-598. https://doi.org/10.59543/comdem.v2i.13855

Karabasevic, D., Radanov, P., Stanujkic, D., Popovic, G., & Predic, B. (2021). Going green: Strategic evaluation of green ICT adoption in the textile industry by using bipolar fuzzy MULTIMOORA method. *Industria Textila*, *72*(1), 3-10. https://doi.org/10.35530/IT.072.01.1841

Keleş, N. (2024). OECD ülkelerinde kullanılan bilgi ve iletişim teknolojilerinin çok kriterli karar verme yöntemleriyle karşılaştırılması. *Gazi İktisat ve İşletme Dergisi*, *10*(2), 215-229. https://doi.org/10.30855/gjeb.2024.10.2.002

Klein, M. (2020). İşletmelerin dijital dönüşüm senaryoları-kavramsal bir model önerisi. *Elektronik Sosyal Bilimler Dergisi*, *19*(74), 997-1019. https://doi.org/10.17755/esosder.676984

Lal, K. (2007). Globalisation and the adoption of ICTs in Nigerian SMEs. *Science, Technology and Society*, *12*(2), 217-244. https://doi.org/10.1177/097172180701200203

Macit, N. Ş. (2024). Avrupa ve Orta Asya ülkelerinde BİT gelişmişlik düzeyinin entegre MPSI-RAPS yöntemi ile ölçülmesi. *Kafkas Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *15*(29), 24-53. https://doi.org/10.36543/kauiibfd.2024.002

Merkevičius, J., & Yadav, R. (2019). Evaluation of ICT usages in virtual business by applying MCDM methods. *22nd Conference for Young Researchers "Science - Future of Lithuania. Economics and Management, Vilnius Gediminas Technical University, 13-14 February 2019.* https://www.lituanistika.lt/content/96143

Nasri, S. A., Safaie, N., Sarabi, A., Eghbali, A., & Barkhordari, G. (2022). Performance evaluation of ICT companies using hybrid MCDM method in Iran. *Mathematical Problems in Engineering*, *2022*(1), 5308343. https://doi.org/10.1155/2022/5308343

Nour, S. S. O. M. (2005). Science and technology development indicators in the Arab region: A comparative study of Arab Gulf and Mediterranean countries. *Science, Technology and Society*, *10*(2), 249-274. https://doi.org/10.1177/097172180501000204

Özkan, G. S., & Çelik, H. (2018). Bilgi iletişim teknolojileri ile ekonomik büyüme arasındaki ilişki: Türkiye için bir uygulama. *Uluslararası Ticaret ve Ekonomi Araştırmaları Dergisi*, *2*(1), 1-15. https://doi.org/10.30711/utead.405474

Öztaş, T., & Öztaş, G. Z. (2024). Innovation performance analysis of G20 countries: A novel integrated LOPCOW-MAIRCA MCDM approach including the COVID-19 period. *Verimlilik Dergisi*, 1-20. https://doi.org/10.51551/verimlilik.1320794

Perego, A., Perotti, S., & Mangiaracina, R. (2011). ICT for logistics and freight transportation: A literature review and research agenda. *International Journal of Physical Distribution & Logistics Management*, *41*(5), 457-483. https://doi.org/10.1108/09600031111138826

Samargandi, N., Al Mamun, M., Sohag, K., & Alandejani, M. (2019). Women at work in Saudi Arabia: Impact of ICT diffusion and financial development. *Technology in Society*, *59*, 101187. https://doi.org/10.1016/j.techsoc.2019.101187

Setiawan, H., Istiyanto, J. E., Wardoyo, R., & Santoso, P. (2016). The group decision support system to evaluate the ICT project performance using the hybrid method of AHP, TOPSIS and Copeland score. *International Journal of Advanced Computer Science and Applications*, *7*(4). https://doi.org/10.14569/IJACSA.2016.070444

Setiawansyah, S., Fernando, Y., Wahyudi, A. D., Wibawa, Y. E., & Nuris, N. (2025). Improving decision accuracy through LOPCOW weighting and AROMAN methods in retail store location selection. *Jurnal Ilmiah Informatika dan Ilmu Komputer (JIMA-ILKOM)*, *4*(1), 77-88. https://doi.org/10.58602/jima-ilkom.v4i1.57

The Visegrad Group. (2025). *About the Visegrad Group.* Available at: https://www.visegradgroup.eu/home

Torkayesh, A. E., & Torkayesh, S. E. (2021). Evaluation of information and communication technology development in G7 countries: An integrated MCDM approach. *Technology in Society*, *66*, 101670. https://doi.org/10.1016/j.techsoc.2021.101670

Torkayesh, A. E., Ecer, F., Pamucar, D., & Karamaşa, Ç. (2021). Comparative assessment of social sustainability performance: Integrated data-driven weighting system and CoCoSo model. *Sustainable Cities and Society*, *71*, 102975. https://doi.org/10.1016/j.scs.2021.102975

Torres, P. S., Gomes, C. F. S., & Santos, M. D. (2024). Selection of unmanned aerial vehicle systems for border monitoring using the MPSI-SPOTIS method. *Journal of Defense Analytics and Logistics*, *8*(1), 80-104. https://doi.org/10.1108/JDAL-12-2023-0016

Ulutaş, A., Balo, F., & Topal, A. (2023). Identifying the most efficient natural fibre for common commercial building insulation materials with an integrated PSI, MEREC, LOPCOW and MCRAT model. *Polymers*, *15*(6), 1500. https://doi.org/10.3390/polym15061500

Wang, Q., Hu, S., & Li, R. (2024). Could information and communication technology (ICT) reduce carbon emissions? The role of trade openness and financial development. *Telecommunications Policy*, *48*(3), 102699. https://doi.org/10.1016/j.telpol.2023.102699

Wittig Vianna, V., dos Santos, M., Francisco Simões Gomes, C., & Lauro, A. (2025). Application of the MPSI-CoCoSo method to rank OECD member countries towards the energy transition. *Computational Economics*, 1-30. https://doi.org/10.1007/s10614-025-10963-8

Yakut, E. (2020). OECD ülkelerinin bilgi ve iletişim teknolojileri gelişmişliklerinin MOORA ve WASPAS yöntemiyle değerlendirilerek kullanılan yöntemlerin Copeland yöntemiyle karşılaştırılması. *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *24*(3), 1275-1294. Available at: https://dergipark.org.tr/en/download/article-file/1205854

Yaprakli, S., & Saglam, T. (2010). Türkiye'de bilgi iletisim teknolojileri ve ekonomik büyüme: Ekonometrik bir analiz (1980-2008). *Ege Akademik Bakis*, *10*(2), 575. Available at: https://dergipark.org.tr/tr/download/article-file/558355

Yeşiltaş, S., & Erdem, T. (2021). Vişegrad grubu üzerine bir analiz: Oluşumu, işleyişi, etkileri ve sorunlar. *OPUS International Journal of Society Researches*, *18*(40), 2961-2998. https://doi.org/10.26466/opus.871140

Yılmaz, N. (2023). Financial performance analysis of multi-branch banks with integrated MPSI-MARA model: The case of Türkiye. *Ekonomi ve Finansal Araştırmalar Dergisi*, *5*(2), 168-188. https://doi.org/10.56668/jefr.1384058