



## ASSESSMENT OF LOGISTICS INFRASTRUCTURE AND SERVICE INDICATORS IN BLACK SEA ECONOMIC COOPERATION (BSEC) COUNTRIES

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### ABSTRACT

In line with the increasing importance of global logistics efficiency, the analysis of countries' strengths and weaknesses in logistics performance indicators has become a strategic necessity for regional integration and global competitiveness. This study aims to evaluate the logistics infrastructure and service indicators of the Black Sea Economic Cooperation (BSEC) countries using an integrated Entropy-EDAS approach, which is among the multi-criteria decision-making (MCDM) methods. In this context, the study utilizes the data from the Logistics Performance Index (LPI) published by the World Bank for the years 2016, 2018, and 2023. The sub-components of the index—namely customs management, infrastructure, international shipments, quality of logistics services, tracking and tracing, and timeliness—were incorporated into the analysis as criteria. The twelve BSEC member countries were defined as the alternatives. The weights of the criteria were objectively calculated through the Entropy method, while the logistics performance of the BSEC countries was ranked using the EDAS method. According to the Entropy-based weighting, timeliness was identified as the most influential criterion affecting logistics performance in both 2016 and 2023. The findings indicate that Türkiye ranked first in terms of logistics performance among BSEC countries in 2016, followed by Greece and Romania in second and third place, respectively. In 2018, Greece rose to the top, with Türkiye and Romania ranking second and third again. This order remained unchanged in 2023. On the other hand, Albania, Armenia, Georgia, and Moldova consistently ranked lowest in terms of logistics infrastructure and service indicators across the analyzed years. The results obtained provide an objective assessment of the customs procedures, infrastructure, and logistics service levels of BSEC countries and offer policy recommendations aimed at enhancing regional logistics strategies.

**Keywords:** Black Sea economic cooperation, logistics performance, multi-criteria decision-making, Entropy, EDAS

### KARADENİZ EKONOMİK İŞ BİRLİĞİ ÜLKELERİNDE LOJİSTİK ALTYAPI VE HİZMET GÖSTERGELERİNİN DEĞERLENDİRİLMESİ

#### ÖZ

Küresel lojistik verimliliğin artan önemi doğrultusunda ülkelerin lojistik performans göstergelerinde güçlü ve zayıf yönlerinin analizi bölgesel entegrasyon ve küresel rekabet gücü açısından stratejik bir gereklilik haline gelmiştir. Bu çalışma, Karadeniz Ekonomik İş Birliği (KEİ) ülkelerinin lojistik altyapı ve hizmet göstergelerini çok kriterli karar verme yöntemlerinden Entropi-EDAS entegre yaklaşımıyla değerlendirmeyi amaçlamaktadır. Bu bağlamda çalışmada, Dünya Bankası tarafından yayımlanan Lojistik Performans Endeksi'nin (LPE) 2016, 2018 ve 2023 verileri ele alınmıştır. Endeksin alt bileşenleri olan gümrük yönetimi altyapı, uluslararası sevkiyat, lojistik hizmet kalitesi, takip ve izleme ve zamanlama kriterler olarak analize dahil edilmiştir. KEİ üyesi 12 ülke ise alternatifler olarak belirlenmiştir. Çalışmadaki kriterlerin ağırlıkları entropi yöntemi ile nesnel olarak hesaplanmış, KEİ üyesi ülkelerin lojistik performansı ise EDAS yöntemiyle sıralanarak değerlendirilmiştir. Entropi ile yapılan ağırlıklandırmada lojistik performansı etkileyen en önemli iki kriter 2016 ve 2023 için zamanlama olmuştur. Elde edilen bulgulara göre; 2016'da KEİ ülkeleri için lojistik performansı en yüksek ülke Türkiye iken ikinci ve üçüncü olan ülkeler sırasıyla Yunanistan

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ve Romanya'dır. 2018'de Yunanistan birinci sıraya yükselmiş, Türkiye ikinci Romanya ise üçüncü sırada yer almıştır. 2023 yılında da bu ülkeler aynı sıralamayla yerini korumuştur. Arnavutluk, Ermenistan, Gürcistan ve Moldova ise ele alınan yıllar içerisinde lojistik altyapı ve hizmet göstergeleri açısından en düşük sıralamaya sahip olan ülkelerdir. Elde edilen sonuçlar, KEİ üyesi ülkelerin gümrük, altyapı ve lojistik hizmet düzeylerinin nesnel verilerle analiz edilmesini sağlayarak, bölgesel lojistik stratejilerinin geliştirilmesine yönelik politika önerileri sunmaktadır.

**Anahtar Kelimeler:** Karadeniz Ekonomik iş birliği, lojistik performans, çok kriterli karar verme, Entropi, EDAS

## **Introduction**

Logistics performance refers to a country's capacity to ensure the efficient, cost-effective, reliable, and timely movement of goods throughout the supply chain in international trade. As highlighted in the Logistics Performance Index (LPI) published by the World Bank, this concept encompasses various elements, including infrastructure quality, customs procedures, the competence of transport services, traceability, and timely delivery. A high level of logistics performance enables a country to gain a competitive advantage in global trade. In this regard, LPI data offer valuable insights into the challenges and opportunities that countries face in conducting international logistics operations. Moreover, these indicators assist policymakers in formulating strategies to enhance performance (World Bank, 2023).

The countries within the scope of this study—the member states of the Black Sea Economic Cooperation (BSEC)—are strategically positioned as a bridge between Europe and Asia and collectively host 56 ports, 32 of which operate at an international scale (Değerli Çiftçi & Baycan, 2023, p. 65). Among them, Greece, Bulgaria, Romania, and Türkiye are connected to the European Union, while Georgia, Azerbaijan, and Armenia serve as corridors to Central Asia and China. Due to their geostrategic location, BSEC countries hold critical significance in global trade routes.

Although BSEC countries occupy a geopolitically strategic location, the socio-political and economic transformations following the dissolution of the Soviet Union brought about significant structural changes, particularly in newly independent states such as Azerbaijan, Armenia, Georgia, Moldova, Russia, and Ukraine. This post-Soviet transitional period not only involved shifts in political regimes but also revealed a pressing need for the restructuring of foreign trade relations, customs systems, and logistics infrastructures in these countries. According to Popa (2017, p. 167), in many transition economies, culture was employed as a means of democratization and identity construction; however, this approach simultaneously laid the foundation for enhanced regional integration and mutual interdependence through trade cooperation.

In this context, facilitating trade, developing transport corridors, and improving logistics infrastructure within the BSEC region support broader goals, such as regional stability and economic development. Transport infrastructure projects and efforts to enhance logistics systems in these regions contribute not only to the advancement of intra-regional trade but also to the deeper integration of these countries into global supply chains (Öztürk, 2025, p. 723). Therefore, conducting a quantitative analysis and comparison of the logistics performance of BSEC countries is of critical importance. Such an approach allows for the identification of which performance criteria hold greater significance and which countries lag behind in the overall ranking. A review of the existing literature reveals that Multi-Criteria Decision-Making (MCDM) methods are frequently employed in the analysis of national logistics performance levels. These studies exhibit diversity not only in the methodologies adopted but also in terms of the geographical regions they address.

An evaluation of the geographical scope of existing studies reveals a particular concentration on the European Union (Ulutaş & Karaköy, 2019; Gürler et al., 2024), OECD countries (Gök Kısa & Ayçin, 2019; Özekenci, 2025), G20 nations (Pehlivan et al., 2024; Gelmez et al., 2024), and members of the Regional Comprehensive Economic Partnership (RCEP) (Türkoğlu & Duran, 2023). In addition, several studies have conducted regional analyses focusing on Asia (Oğuz et al., 2019) and Central and Eastern Europe (Işık et al., 2020). However, no comprehensive assessment has been identified in the literature that specifically examines the logistics performance of the Black Sea Economic Cooperation (BSEC) countries.

Most of these studies focus on evaluating national logistics capacities based on the components of the Logistics Performance Index (LPI). Therefore, this study, which analyzes the logistics performance levels of BSEC countries using LPI indicators, is expected to contribute to the literature by aligning methodologically with existing research while simultaneously addressing a gap by providing a comparative, year-based analysis of the logistics performance of BSEC countries, an area that remains largely unexplored.

Accordingly, this study utilizes the LPI data published for the years 2016, 2018, and 2023 to analyze six sub-indicators of the index through an Entropy-based EDAS (Evaluation Based on Distance from Average Solution) approach. Based on the analysis, the most significant criteria for the years 2016, 2018, and 2023 were identified, and the countries that ranked highest and lowest in terms of logistics performance were compared. These findings are subsequently used to offer relevant policy recommendations.

### **Literature Review**

The Logistics Performance Index (LPI) is a widely utilized indicator for measuring the efficiency of national logistics systems. Within academic literature, numerous studies have examined the sub-components of this index by applying Multi-Criteria Decision-Making (MCDM) methods to analyze the logistics performance of various countries or economic blocs. These studies provide systematic, objective, and comparable evaluations of national logistics capacities.

Stević et al. (2024), for instance, analyzed LPI data from the period 2010–2023 using methods such as TOPSIS, SAW, and FUCA, obtaining results that were consistent with global rankings. Ulutaş and Karaköy (2019) employed a hybrid approach combining subjective and objective weighting methods to rank the logistics performance of European Union countries through the PIV method. Similarly, Çıray et al. (2024) utilized an Entropy-ORESTE approach to identify the most influential criteria within the LPI framework. Türkoğlu and Duran (2023) evaluated RCEP (Regional Comprehensive Economic Partnership) member countries using CRITIC, WASPAS, and GIA methods, while Gürler et al. (2024) analyzed EU countries through a genetic algorithm-supported weighting model. Pehlivan et al. (2024) and Gelmez et al. (2024) assessed the logistics performance of G20 countries using TOPSIS and SD-COPRAS-SAW approaches. Moreover, Özekenci (2025) employed hybrid models to analyze OECD countries, and Yılmaz (2025) examined top-performing countries in the LPI based on their levels of digitalization using an integrated CRITIC–TOPSIS method.

Collectively, these studies contribute valuable insights into the evaluation of logistics performance across diverse regions and criteria and further demonstrate the applicability and effectiveness of MCDM techniques in logistics-related research.

A comprehensive review of the literature reveals that Multi-Criteria Decision-Making (MCDM) methods are extensively employed in country-level analyses of logistics performance. The existing body of research exhibits diversity both in methodological approaches and geographical coverage. A significant portion of the reviewed studies is based on the sub-components of the World Bank's Logistics Performance Index (LPI), aiming to assess countries' logistics capacities through these indicators. In the weighting of criteria, a combination of subjective and objective approaches has been adopted. Notably, objective, data-driven weighting methods such as CRITIC, Entropy, SWARA, and Standard Deviation (SD) have been widely applied. These methodological tendencies highlight the LPI as a widely accepted and reliable indicator in logistics performance research, owing to its data accessibility and suitability for global benchmarking. In this regard, the present study's use of LPI indicators as a basis for evaluating the logistics performance of BSEC ensures methodological consistency with existing literature.

**Table 1.** Studies Incorporating the LPI and MCDM Methods

| Author(s)              | Purpose and Methods                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Key Findings                                                                                                                                                                                                                                                                                                                         |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Yilmaz (2025)          | The aim of this study is to analyze the digitalization levels of top-performing countries in the LPI and to evaluate the impact of these levels on logistics performance using a Multi-Criteria Decision-Making (MCDM) approach. Accordingly, the countries were selected based on their 2023 LPI rankings, and six different digitalization indices were used as evaluation criteria.                                                                                   | According to the analysis, among the high-performing countries, Singapore, the United States, and the Netherlands ranked highest in terms of digitalization levels. The study highlights a significant relationship between countries' digitalization scores and their LPI rankings.                                                 |
| Özekenci (2025)        | This study aims to evaluate the Logistics Performance Index (LPI) of OECD countries using Multi-Criteria Decision-Making (MCDM) methods. Accordingly, criterion weights were determined using objective weighting techniques such as Standard Deviation (SD), CRITIC, LOPCOW, and MEREC, and then aggregated using the Aggregate Weighting Method (AWM). Subsequently, countries were ranked using the CRADIS method. The analysis was based on data from the year 2023. | According to the analysis, the two most important criteria were tracking and tracing. In contrast, the logistics competence and quality criterion was identified as the least significant. Finland ranked as the top-performing country in terms of logistics performance, while Costa Rica was placed at the bottom of the ranking. |
| Stević et al. (2024)   | This study evaluates the LPI indicators developed by the World Bank for 118 countries using MCRA, SAW, TOPSIS, and FUCA methods. The analysis is based on LPI data from the years 2010 to 2023.                                                                                                                                                                                                                                                                          | According to the analyses, Germany and Singapore consistently ranked among the top performers in the period between 2010 and 2023. Germany held the highest rankings across all years. In addition to these countries, Sweden, Belgium, Switzerland, Finland, and Japan also stood out as nations with high LPI scores.              |
| Pehlivan et al. (2024) | The aim of this study is to rank the logistics performance of G20 countries for the year 2023 using the TOPSIS method and to classify the countries through cluster analysis. The TOPSIS method was employed as the MCDM technique, while the Ward method was used for the clustering analysis.                                                                                                                                                                          | According to the findings, the first cluster—comprising countries with the highest LPI performance—includes Germany, the United States, and Australia. The third cluster consists of Brazil, India, Saudi Arabia, and Türkiye.                                                                                                       |
| Gürler et al. (2024)   | This study proposes a Genetic Algorithm-based approach to determine criterion                                                                                                                                                                                                                                                                                                                                                                                            | According to the analysis results, the three most heavily weighted criteria were export value of goods, road                                                                                                                                                                                                                         |

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|                         | weights more objectively in the evaluation of the logistics performance of EU countries using MCDM methods. A total of 11 methods were employed in the study, including ARAS, CoCoSo, CODAS, COPRAS, EDAS, GRA, MABAC, MARCOS, MOORA, OCRA, and WASPAS. Criterion weights were generated using the Genetic Algorithm technique, and the analyses were conducted using data from the year 2018.                                                               | quality, and gross domestic product (GDP) per capita. The weights determined by the Genetic Algorithm showed a higher correlation with the World Bank's LPI rankings compared to the CRITIC, Entropy, and equal weighting methods. Based on both the analysis results and the LPI rankings, Germany was identified as the country with the highest logistics performance.                                                            |
| Gelmez et al. (2024)    | This study aims to evaluate the logistics performance of G20 countries using COPRAS and SAW methods based on the Standard Deviation (SD) approach. In this context, LPI data from the years 2018 and 2023 were utilized.                                                                                                                                                                                                                                     | The findings revealed that Germany, Japan, the United Kingdom, and Canada had the highest logistics performance levels in both 2018 and 2023. Customs procedures and infrastructure were identified as the most critical criteria. The decline in the United Kingdom's performance was attributed to the impact of the Brexit Agreement and the COVID-19 pandemic on the country's logistics operations during the respective years. |
| Çıray et al. (2024)     | This study aims to analyze the 2023 LPI data using the integrated ENTROPY-ORESTE method. In this context, a more objective and systematic approach is proposed, as opposed to traditional ranking methods that rely on expert judgment.                                                                                                                                                                                                                      | The findings indicate that infrastructure and customs procedures are the most heavily weighted criteria. According to the ranking produced by the ORESTE method, Singapore, Finland, and Switzerland are identified as the top three countries in terms of LPI. The study demonstrates that the methods employed provide more objective, consistent, and sensitive results compared to traditional LPI rankings.                     |
| Türkoğlu & Duran (2023) | In this study, the LPI data of the Regional Comprehensive Economic Partnership (RCEP) member countries were evaluated using Multi-Criteria Decision-Making (MCDM) methods. Criterion weights were determined through the CRITIC method, while country rankings were analyzed using the WASPAS and GIA techniques.                                                                                                                                            | Customs management was identified as the most significant criterion according to the CRITIC-based weighting. In the analyses conducted using the WASPAS and GIA methods, Singapore, Japan, and New Zealand emerged as the top-performing countries. Conversely, Myanmar, Cambodia, and Laos were ranked among the lowest in terms of LPI scores.                                                                                     |
| Oğuz (2023)             | In this study, the top 10 countries in the Logistics Performance Index (LPI) were analyzed using the TOPSIS and EDAS methods, which are among the Multi-Criteria Decision-Making (MCDM) approaches. The analysis was conducted based on data from the year 2023.                                                                                                                                                                                             | According to the analysis results, Finland, Singapore, and Austria were identified as the top-performing countries in the TOPSIS evaluation, while Singapore, Finland, and Switzerland ranked highest based on the EDAS method.                                                                                                                                                                                                      |
| Çalık et al. (2023)     | This study aims to develop a novel evaluation model for assessing the Logistics Performance Index (LPI) by integrating classical and various fuzzy environment-based MCDM methods. The weighting procedures employed include AHP, FAHP, and PFAHP, while the ranking methods consist of TOPSIS, CODAS, and VIKOR. The final results were aggregated using the Borda Count Method. A total of 160 countries were included in the analysis based on 2018 data. | .According to the analysis results, the outcomes of the proposed model were found to be consistent with the World Bank's rankings. Infrastructure was identified as the most important criterion, whereas tracking and tracing ranked lowest in terms of significance. Based on the criterion weightings and country rankings, the study recommends prioritizing investments in infrastructure and logistics quality.                |

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|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Işık et al. (2020)      | This study aims to analyze the logistics performance of Central and Eastern European countries using Statistical Variance (SV) and the MABAC method. In this context, 11 countries were included in the analysis, which was conducted using data from the year 2018.                                                                                                                                                                                                                                                                                                                   | According to the findings, timeliness and international shipments emerged as the most important criteria for the logistics performance of these countries, while infrastructure was identified as the least significant indicator. The Czech Republic, Poland, and Hungary were among the top-performing countries. For lower-performing countries such as Latvia, Lithuania, and Slovakia, investments in timeliness and international shipment capabilities were recommended. |
| Ulutaş & Karaköy (2019) | This study aimed to evaluate the Logistics Performance Index (LPI) indicators of European Union (EU) countries by combining the subjective SWARA and objective CRITIC weighting methods to determine criterion weights and rank the countries. This integrated approach was intended to ensure a more balanced determination of criterion importance and to enable a more accurate assessment of logistics performance. The decision-making and ranking processes were conducted using the PIV method. A total of 28 EU member states were included in the analysis for the year 2018. | According to the analysis results, the integration of both subjective and objective weighting approaches identified infrastructure as the most significant criterion. For the year 2018, Germany was determined to have the highest logistics performance among the analyzed countries. The study recommends the use of measurement-based MCDM methods instead of equal weighting across indicators to ensure more accurate results when utilizing the LPI.                     |
| Oğuz et al. (2019)      | In this study, seven Asian countries were ranked based on their LPI data using the TOPSIS method. The analysis was conducted using data from the year 2018.                                                                                                                                                                                                                                                                                                                                                                                                                            | The results of the study show that Singapore demonstrated the highest performance across all criteria and ranked first in the overall performance ranking. South Korea and Taiwan also ranked among the high-performing countries. It was recommended that countries such as Indonesia and Malaysia improve their infrastructure investments and logistics systems.                                                                                                             |
| Gök Kısa & Ayçin (2019) | The aim of this study is to analyze the logistics performance of OECD countries using LPI data through the SWARA and EDAS methods.                                                                                                                                                                                                                                                                                                                                                                                                                                                     | The results indicate that logistics service quality and infrastructure are the most important criteria. Germany, the Netherlands, and Sweden were identified as the top-performing countries in terms of logistics performance. Türkiye ranked 27th among the evaluated countries. Accordingly, the study recommends that Türkiye increase its investments in infrastructure and enhance the quality of its logistics services.                                                 |

In the majority of studies, infrastructure and customs procedures stand out as the most prominent criteria. In a more limited number of studies, tracking and tracing systems, along with delivery speed, have also been highlighted as highly significant factors in determining logistics performance. When the geographical scope of the literature is examined, it becomes evident that a substantial focus has been placed on the European Union (EU), the OECD, G20, and RCEP countries. Regional analyses covering Asia and Central and Eastern Europe are also present in the literature. However, within this framework, no direct evaluation has been found that specifically addresses the logistics performance of the Black Sea Economic Cooperation (BSEC) countries. Therefore, a study that assesses the logistics performance of BSEC countries using Multi-Criteria Decision-Making (MCDM) methods is expected to fill an important gap in existing literature.

From a data perspective, the years 2018 and 2023 are frequently used in LPI assessments, while some studies have adopted long-term data analysis to examine trends over extended periods. In many of these studies, countries such as Germany, Singapore, and Finland consistently rank at the top due to their high logistics performance. In contrast, Türkiye is generally positioned among countries with moderate performance levels, with common recommendations focusing on improving infrastructure and service quality. These findings from the literature indicate that logistics performance analyses go beyond merely describing the current state; they also reveal which criteria countries excel in or fall behind on, thereby laying the groundwork for comparative evaluations. In this context, such analyses contribute meaningfully to decision-making processes aimed at strategically enhancing national logistics capacities.

### **Methodology**

This study utilizes LPI data published in the years 2016, 2018, and 2023. The Logistics Performance Index (LPI) is an interactive benchmarking tool designed to evaluate countries' trade logistics performance across six indicators, helping them identify challenges and improvement opportunities. The index includes elements such as the efficiency of customs procedures, quality of infrastructure, and the timeliness of deliveries. The data used in the rankings are derived from a survey conducted among logistics professionals, who assess the trade logistics performance of the foreign countries with which they operate. As of 2023, the LPI allows for comparative assessments across 139 countries (World Bank, 2023).

In this study, the Entropy and EDAS approaches, both of which are Multi-Criteria Decision-Making (MCDM) methods, were applied. First, the significance levels of the LPI indicators for BSEC countries were determined using the Entropy method. Subsequently, the countries were ranked using the EDAS method. Entropy was employed to calculate the weights of the criteria in the decision matrix, while EDAS was used to rank the decision alternatives. Detailed information regarding the methodology is provided below.

#### **1. Entropy Method**

In Multi-Criteria Decision-Making (MCDM) approaches, various methods have been developed to ensure the objectivity of the decision-making process and to determine the relative influence of each criterion. A wide range of such methods has been applied in the literature, with the entropy method being one of the most frequently used. This technique stands out for its ability to calculate the weights of criteria independently of the subjective judgments of decision-makers (Çatı et al., 2014, p. 204).

In this study, the Entropy method was selected to objectively determine the importance levels of the identified criteria. The Entropy approach determines the weights of the criteria based directly on the data provided in the decision matrix. As it can be implemented without requiring expert opinion or personal judgment, the method offers advantages in terms of practicality and impartiality. Its most prominent strength lies in its ability to compute the relative impact of each criterion solely through numerical data, thereby eliminating subjective influences from the decision-making process (Ayçin, 2020, p. 132).

The implementation steps of this method are defined by Hwang and Yoon (1981, pp. 53–54) as follows:

##### ***Step 1: Construction of the Decision Matrix***

$$D = \begin{bmatrix} X_1 & X_2 & X_n \\ X_{11} & X_{12} & X_{1n} \\ X_{21} & X_{22} & X_{2n} \\ \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & X_{mn} \end{bmatrix} \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \quad (1)$$

A: Alternative, X: Criteria and  $X_{mn}$ : the value of alternative m with respect to criterion n. The matrix is formed by determining the number of alternatives m and the number of criteria n.

**Step 2: Normalization of criterion values**

The values of criteria with different units of measurement are normalized by calculating  $P_{ij}$  values:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}; \forall i, j \quad (2)$$

**Step 3: Calculating  $E_j$  (entropy of value j)**

$$E_j = -k \sum_{i=1}^m [P_{ij} \ln P_{ij}]; \forall j \quad (3)$$

Here k is a constant and is calculated with the formula  $k = 1 / \ln(m)$ . The value of  $E_j$  is also guaranteed to be  $0 < E_j < 1$

**Step 4: Calculating  $d_j$  as the degree of diversity of the information obtained from the results of criterion j**

$$d_j = 1 - E_j; \forall j \quad (4)$$

**Step 5: Calculation of  $w_j$  weights as the degree of importance of criterion j**

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j}; \forall j \quad (5)$$

## 2. EDAS Method

In this study, the EDAS (Evaluation based on Distance from Average Solution) method was employed to evaluate the logistics performance indicators of the alternatives, and the alternatives were ranked based on the resulting weight values derived from the evaluation. The EDAS method provides an objective assessment framework within multi-criteria decision-making (MCDM) processes by considering the distances of alternatives from both the positive and negative average solutions. The implementation of the method follows a structured set of steps as defined by Ghorabae et al. (2015: 438–440).

**Step 1: Selecting the most important criteria defining the alternatives**

**Step 2: Creating the decision-making matrix (X)**

$$X = [X_{ij}]_{n \times m} = \begin{bmatrix} X_{11} & X_{12} & X_{1m} \\ X_{21} & X_{22} & X_{2m} \\ \vdots & \vdots & \vdots \\ X_{n1} & X_{n2} & X_{nm} \end{bmatrix} \quad (6)$$

$X_{ij}$  represents the performance value of alternative  $i$  according to criterion  $j$ .

**Step 3:** Determining the average solution for all criteria.

$$AV = [AV_j]_{1 \times m} \quad (7)$$

$AV_j$  in the formula is calculated as follows:

$$AV_j = \frac{\sum_{i=1}^n X_{ij}}{n} \quad (8)$$

**Step 4:** Calculating the negative distance from the mean (NDA) and positive distance from the mean (PDA) by criterion type (benefit and cost)

$$PDA = [PDA_{ij}]_{n \times m} \quad (9)$$

$$NDA = [NDA_{ij}]_{n \times m} \quad (10)$$

If criterion  $j$ -th is a utility-based criterion;

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad (11)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad (12)$$

If criterion  $j$ -th is a cost-based criterion;

$$PDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad (13)$$

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad (14)$$

$PDA_{ij}$ : It refers to the positive distance of the  $i$ -th alternative from the average solution with respect to the  $j$ -th criterion.

$NDA_{ij}$ : It denotes the negative distance of the  $i$ -th alternative from the average solution with respect to the  $j$ -th criterion.

**Step 5:** Determination of the weighted sum of the Positive Distance from Average (PDA) and Negative Distance from Average (NDA) for all alternatives.

$$SP_i = \sum_{j=1}^m w_j PDA_{ij} \quad (15)$$

$$SP_j = \sum_{j=1}^m w_j NDA_{ij} \quad (16)$$

$w_j$  : j-th denotes the weight of the j-th criterion.

**Step 6:** Normalization of  $SP_i$  and  $SN_i$  values for all criteria

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (17)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \quad (18)$$

**Step 7:** Calculation of the assessment scores (AS) for each alternative

$$AS_i = \frac{1}{2} (NSP_i + NSN_i), \quad (19)$$

$0 \leq AS_i \leq 1$   $AS_i$  value must be between 0 and 1

**Step 8:** The alternatives are ranked in descending order based on their assessment scores (AS). The alternative with the highest AS value is identified as the most favorable option among the available alternatives. All other alternatives are classified according to this ranking.

### Application and Findings

In this section, the findings of the analyses conducted for weighting the criteria and ranking the countries are presented.

#### 1. Determination of Criterion Weights Using the Entropy Method

The LPI (Logistics Performance Index) scores of the BSEC (Black Sea Economic Cooperation) member states, which constitute the decision alternatives, have been considered as the evaluation criteria. In this context, the dataset used in the study consists of decision matrices developed based on logistics performance indicators. As the study involves a comparative analysis across three different years, the decision matrices for each respective year are presented in Table 2.

**Table 2.** Decision Matrices for the Years 2016, 2018, and 2023 for BSEC Countries

| Country         | 2016    |                |                         |                                          |                      |            |
|-----------------|---------|----------------|-------------------------|------------------------------------------|----------------------|------------|
|                 | Customs | Infrastructure | International Shipments | Logistics Service Quality and Competence | Tracking and Tracing | Timeliness |
| Albania         | 2,23    | 1,98           | 2,48                    | 2,48                                     | 2,15                 | 3,05       |
| Bulgaria        | 2,40    | 2,35           | 2,93                    | 3,06                                     | 2,72                 | 3,31       |
| Armenia         | 1,95    | 2,22           | 2,22                    | 2,21                                     | 2,02                 | 2,60       |
| Georgia         | 2,26    | 2,17           | 2,35                    | 2,08                                     | 2,44                 | 2,80       |
| North Macedonia | 2,21    | 2,58           | 2,45                    | 2,36                                     | 2,32                 | 3,13       |
| Moldova         | 2,39    | 2,35           | 2,60                    | 2,48                                     | 2,67                 | 3,16       |
| Romania         | 3,00    | 2,88           | 3,06                    | 2,82                                     | 2,95                 | 3,22       |
| Russia          | 2,01    | 2,43           | 2,45                    | 2,76                                     | 2,62                 | 3,15       |

|                 |      |      |      |      |      |      |
|-----------------|------|------|------|------|------|------|
| Serbia          | 2,50 | 2,49 | 2,63 | 2,79 | 2,92 | 3,23 |
| Türkiye         | 3,18 | 3,49 | 3,41 | 3,31 | 3,39 | 3,75 |
| Ukraine         | 2,30 | 2,49 | 2,59 | 2,55 | 2,96 | 3,51 |
| Greece          | 2,85 | 3,32 | 2,97 | 2,91 | 3,59 | 3,85 |
| <b>2018</b>     |      |      |      |      |      |      |
| Albania         | 2,35 | 2,29 | 2,82 | 2,56 | 2,67 | 3,20 |
| Bulgaria        | 2,94 | 2,76 | 3,23 | 2,88 | 3,02 | 3,31 |
| Armenia         | 2,57 | 2,48 | 2,65 | 2,50 | 2,51 | 2,90 |
| Georgia         | 2,42 | 2,38 | 2,38 | 2,26 | 2,26 | 2,95 |
| North Macedonia | 2,45 | 2,47 | 2,84 | 2,74 | 2,64 | 3,03 |
| Moldova         | 2,25 | 2,02 | 2,69 | 2,30 | 2,21 | 3,17 |
| Romania         | 2,58 | 2,91 | 3,18 | 3,07 | 3,26 | 3,68 |
| Russia          | 2,42 | 2,78 | 2,64 | 2,75 | 2,65 | 3,31 |
| Serbia          | 2,60 | 2,60 | 2,97 | 2,70 | 2,79 | 3,33 |
| Türkiye         | 2,71 | 3,21 | 3,06 | 3,05 | 3,23 | 3,63 |
| Ukraine         | 2,49 | 2,22 | 2,83 | 2,84 | 3,11 | 3,42 |
| Greece          | 2,84 | 3,17 | 3,30 | 3,06 | 3,18 | 3,66 |
| <b>2023</b>     |      |      |      |      |      |      |
| Albania         | 2,4  | 2,7  | 2,8  | 2,3  | 2,5  | 2,3  |
| Bulgaria        | 3,1  | 3,1  | 3,0  | 3,3  | 3,5  | 3,3  |
| Armenia         | 2,5  | 2,6  | 2,2  | 2,6  | 2,7  | 2,3  |
| Georgia         | 2,6  | 2,3  | 2,7  | 2,6  | 3,1  | 2,8  |
| North Macedonia | 3,1  | 3,0  | 2,8  | 3,2  | 3,5  | 3,2  |
| Moldova         | 1,9  | 1,9  | 2,7  | 2,8  | 3,0  | 2,8  |
| Romania         | 2,7  | 2,9  | 3,4  | 3,3  | 3,6  | 3,5  |
| Russia          | 2,4  | 2,7  | 2,3  | 2,6  | 2,9  | 2,5  |
| Serbia          | 2,2  | 2,4  | 2,9  | 2,7  | 3,4  | 2,9  |
| Türkiye         | 3    | 3,4  | 3,4  | 3,5  | 3,6  | 3,5  |
| Ukraine         | 2,4  | 2,4  | 2,8  | 2,6  | 3,1  | 2,6  |
| Greece          | 3,2  | 3,7  | 3,8  | 3,8  | 3,9  | 3,9  |

The decision matrix presented in Table 2 has been normalized using Equation (2) with respect to the criteria under consideration. The normalized decision matrices for the years 2016, 2020, and 2023 are provided in Table 3.

**Table 3.** Normalized Decision Matrices for BSEC Countries Based on the Entropy Method

| 2016                 |             |                     |                                   |                                                   |                         |            |
|----------------------|-------------|---------------------|-----------------------------------|---------------------------------------------------|-------------------------|------------|
| Country              | Customs     | Infrastruc-<br>ture | Interna-<br>tional Ship-<br>ments | Logistics<br>Service<br>Quality and<br>Competence | Tracking<br>and Tracing | Timeliness |
| Albania              | 0,07628017  | 0,06440588          | 0,07729047                        | 0,07812776                                        | 0,06569258              | 0,07867821 |
| Bulgaria             | 0,08193392  | 0,07643883          | 0,09113734                        | 0,09613146                                        | 0,08303478              | 0,08535084 |
| Armenia              | 0,06645742  | 0,07207304          | 0,06890185                        | 0,06937629                                        | 0,06173505              | 0,06716273 |
| Georgia              | 0,07711477  | 0,07044396          | 0,07308863                        | 0,06530536                                        | 0,07452155              | 0,07232863 |
| North Mace-<br>donia | 0,07550057  | 0,08391971          | 0,07613893                        | 0,07411644                                        | 0,07090124              | 0,08071378 |
| Moldova              | 0,08172806  | 0,07650021          | 0,08096420                        | 0,07791106                                        | 0,08138497              | 0,08149169 |
| Romania              | 0,10241740  | 0,09371277          | 0,09514440                        | 0,08868282                                        | 0,08993716              | 0,08315949 |
| Russia               | 0,06849775  | 0,07899009          | 0,07622176                        | 0,08679716                                        | 0,07985852              | 0,08134032 |
| Serbia               | 0,08534783  | 0,08099118          | 0,08192808                        | 0,08775645                                        | 0,08914662              | 0,08327166 |
| Türkiye              | 0,10861553  | 0,11358745          | 0,10614253                        | 0,10413747                                        | 0,10364409              | 0,09668776 |
| Ukraine              | 0,07864533  | 0,08111264          | 0,08063353                        | 0,08014475                                        | 0,09045199              | 0,09057903 |
| Greece               | 0,09746125  | 0,10782424          | 0,09240829                        | 0,09151300                                        | 0,10969145              | 0,09923589 |
| 2018                 |             |                     |                                   |                                                   |                         |            |
| Albania              | 0,076626489 | 0,073274951         | 0,081620281                       | 0,078214685                                       | 0,079535699             | 0,08087451 |
| Bulgaria             | 0,095903269 | 0,088267847         | 0,093466813                       | 0,088069609                                       | 0,089968071             | 0,08367309 |
| Armenia              | 0,084026278 | 0,079358691         | 0,076567814                       | 0,076519599                                       | 0,074927299             | 0,07313207 |
| Georgia              | 0,079123687 | 0,076103466         | 0,068662255                       | 0,06897716                                        | 0,06733323              | 0,07437655 |
| North Mace-<br>donia | 0,08007688  | 0,079022741         | 0,082006638                       | 0,083850769                                       | 0,078868627             | 0,07663860 |
| Moldova              | 0,073578212 | 0,064530033         | 0,077845332                       | 0,070297815                                       | 0,065814034             | 0,07996929 |
| Romania              | 0,084252554 | 0,092865497         | 0,091812765                       | 0,093948568                                       | 0,097410627             | 0,09297591 |
| Russia               | 0,079018074 | 0,088657403         | 0,076422515                       | 0,084033552                                       | 0,07895065              | 0,08366834 |
| Serbia               | 0,084788062 | 0,083057078         | 0,085882288                       | 0,082669707                                       | 0,083216548             | 0,08417629 |
| Türkiye              | 0,088586469 | 0,102549324         | 0,088465129                       | 0,093127754                                       | 0,09646565              | 0,09161813 |
| Ukraine              | 0,081329412 | 0,070962725         | 0,08177694                        | 0,086887203                                       | 0,092773046             | 0,08641685 |
| Greece               | 0,092690614 | 0,101350243         | 0,095471232                       | 0,09340358                                        | 0,094736519             | 0,09248039 |
| 2023                 |             |                     |                                   |                                                   |                         |            |
| Albania              | 0,076190476 | 0,081570997         | 0,08045977                        | 0,065155807                                       | 0,06443299              | 0,06460674 |
| Bulgaria             | 0,098412698 | 0,093655589         | 0,086206897                       | 0,093484419                                       | 0,090206186             | 0,09269663 |
| Armenia              | 0,079365079 | 0,078549849         | 0,063218391                       | 0,073654391                                       | 0,069587629             | 0,06460674 |
| Georgia              | 0,082539683 | 0,069486405         | 0,077586207                       | 0,073654391                                       | 0,079896907             | 0,07865169 |
| North Mace-<br>donia | 0,098412698 | 0,090634441         | 0,08045977                        | 0,090651558                                       | 0,090206186             | 0,08988764 |
| Moldova              | 0,06031746  | 0,057401813         | 0,077586207                       | 0,079320113                                       | 0,077319588             | 0,07865169 |

|                |             |             |             |             |             |            |
|----------------|-------------|-------------|-------------|-------------|-------------|------------|
| <b>Romania</b> | 0,085714286 | 0,087613293 | 0,097701149 | 0,093484419 | 0,092783505 | 0,09831461 |
| <b>Russia</b>  | 0,076190476 | 0,081570997 | 0,066091954 | 0,073654391 | 0,074742268 | 0,07022472 |
| <b>Serbia</b>  | 0,06984127  | 0,072507553 | 0,083333333 | 0,076487252 | 0,087628866 | 0,08146067 |
| <b>Türkiye</b> | 0,095238095 | 0,102719033 | 0,097701149 | 0,099150142 | 0,092783505 | 0,09831461 |
| <b>Ukraine</b> | 0,076190476 | 0,072507553 | 0,08045977  | 0,073654391 | 0,079896907 | 0,07303371 |
| <b>Greece</b>  | 0,101587302 | 0,111782477 | 0,109195402 | 0,107648725 | 0,100515464 | 0,10955056 |

The weights of the criteria, calculated using the Entropy method for all criteria and years, are presented in Table 4.

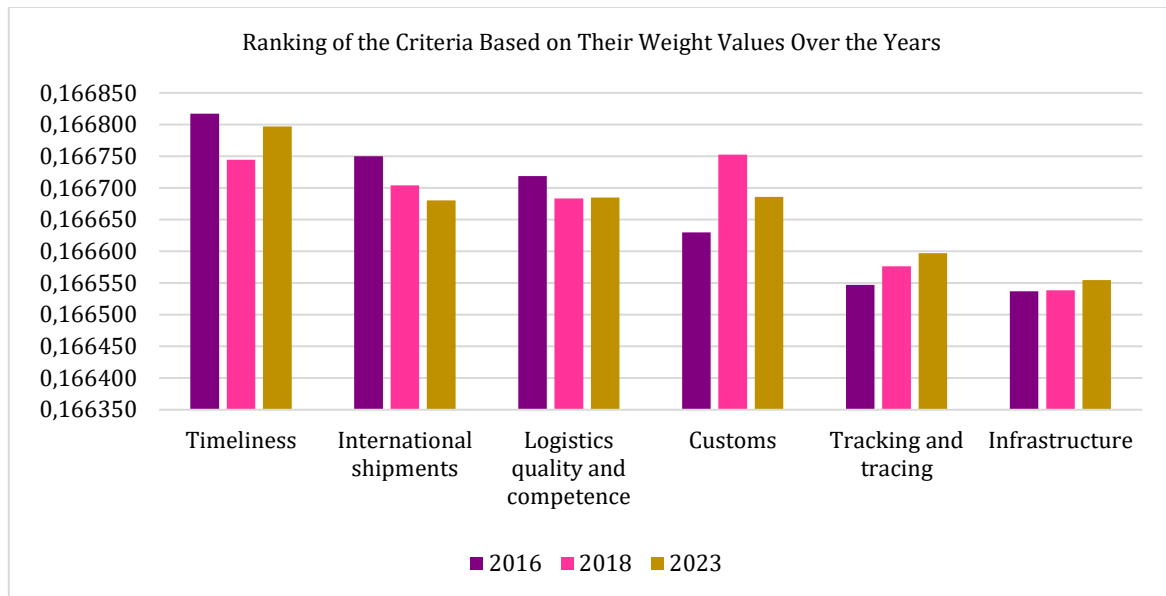
**Table 4.** Criterion Weights Calculated by Year

| Year | Customs  | Infra-structure | International Shipments | Logistics Service Quality and Competence | Tracking and Tracing | Timeliness |
|------|----------|-----------------|-------------------------|------------------------------------------|----------------------|------------|
| 2016 | 0,166630 | 0,166537        | 0,166750                | 0,166719                                 | 0,166547             | 0,166817   |
| 2018 | 0,166753 | 0,166539        | 0,166704                | 0,166683                                 | 0,166576             | 0,166745   |
| 2023 | 0,166686 | 0,166555        | 0,166680                | 0,166685                                 | 0,166797             | 0,166597   |

The change in the weights of the logistics performance index components considered as criteria over the years is presented in Table 5 and Figure 1. Based on the criterion weights, it was determined that in 2016, the three most significant criteria in terms of logistics performance for BSEC countries were, respectively, Timeliness, International Shipments, and Logistics Service Quality and Competence. In 2018, however, the weight of the Customs criterion increased, and the top three criteria became Customs, Timeliness, and International Shipments. According to the weight values for 2023, the top three criteria were identified as Timeliness, Customs, and Logistics Service Quality and Competence, respectively. These results indicate that the most prominent criteria throughout the 2016–2023 period were Timeliness and Customs. It can be particularly noted that the importance of the customs criterion increased most significantly during the transition from 2016 to 2018. Specifically, this criterion rose from fourth place in 2016 to first place in 2018. However, in 2023, it maintained the second position. By contrast, the criterion with consistently lower weights across all years was identified as infrastructure.

**Table 5.** Ranking of Criteria Based on Weight Values by Year

| Ranking | Criteria                                 | 2016     | Criteria                                 | 2018     | Criteria                                 | 2023     |
|---------|------------------------------------------|----------|------------------------------------------|----------|------------------------------------------|----------|
| 1       | Timeliness                               | 0,166817 | Customs                                  | 0,166753 | Timeliness                               | 0,166797 |
| 2       | International Shipments                  | 0,166750 | Timeliness                               | 0,166745 | Customs                                  | 0,166686 |
| 3       | Logistics Service Quality and Competence | 0,166719 | International Shipments                  | 0,166704 | Logistics Service Quality and Competence | 0,166685 |
| 4       | Customs                                  | 0,166630 | Logistics Service Quality and Competence | 0,166683 | International Shipments                  | 0,166680 |
| 5       | Tracking and Tracing                     | 0,166547 | Tracking and Tracing                     | 0,166576 | Tracking and Tracing                     | 0,166597 |
| 6       | Infrastructure                           | 0,166537 | Infrastructure                           | 0,166539 | Infrastructure                           | 0,166555 |



**Graph 1.** Ranking of the Criteria Based on Their Weight Values Over the Years

Based on the criterion weights, the logistics performance of countries was compared using the EDAS method, and the corresponding  $AS_i$  values are presented in Table 6.

**Table 6.**  $AS_i$  Values of the Countries According to the EDAS Method

| Country         | 2016  | 2018  | 2023  |
|-----------------|-------|-------|-------|
| Albania         | 0,184 | 0,280 | 0,024 |
| Bulgaria        | 0,540 | 0,781 | 0,695 |
| Armenia         | 0,000 | 0,239 | 0,000 |
| Georgia         | 0,144 | 0,019 | 0,231 |
| North Macedonia | 0,294 | 0,356 | 0,633 |
| Moldova         | 0,394 | 0,000 | 0,011 |
| Romania         | 0,699 | 0,880 | 0,698 |
| Russia          | 0,345 | 0,430 | 0,095 |
| Serbia          | 0,526 | 0,527 | 0,283 |
| Türkiye         | 1,000 | 0,934 | 0,806 |
| Ukraine         | 0,486 | 0,497 | 0,188 |
| Greece          | 0,869 | 1,000 | 1,000 |

Table 7 presents the ranking of BSEC countries' logistics performance based on the components of the Logistics Performance Index, as calculated using the EDAS method. According to the results, the top three performing countries in 2016 were Türkiye, Greece, and Romania, respectively. In both 2018 and 2023, the ranking shifted slightly, with Greece taking the lead, followed by Türkiye and Romania. As evident from the table, these three countries consistently emerged as the best performers in logistics across the 2016–2023 period.

**Table 7.** Country Rankings According to the EDAS Method

| Ranking | Country | 2016   | Country | 2018   | Country | 2023   |
|---------|---------|--------|---------|--------|---------|--------|
| 1       | Türkiye | 1,0000 | Greece  | 1,0000 | Greece  | 1,0000 |
| 2       | Greece  | 0,8694 | Türkiye | 0,9335 | Türkiye | 0,8062 |
| 3       | Romania | 0,6994 | Romania | 0,8797 | Romania | 0,6982 |

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|    |                 |        |                 |        |                 |        |
|----|-----------------|--------|-----------------|--------|-----------------|--------|
| 4  | Bulgaria        | 0,5397 | Bulgaria        | 0,7806 | Bulgaria        | 0,6948 |
| 5  | Serrbia         | 0,5259 | Serbia          | 0,5268 | North Macedonia | 0,6335 |
| 6  | Ukraine         | 0,4862 | Ukraine         | 0,4974 | Serbia          | 0,2828 |
| 7  | Moldova         | 0,3939 | Russia          | 0,4305 | Georgia         | 0,2312 |
| 8  | Russia          | 0,3447 | North Macedonia | 0,3561 | Ukraine         | 0,1885 |
| 9  | North Macedonia | 0,2938 | Albania         | 0,2804 | Russia          | 0,0950 |
| 10 | Albania         | 0,1845 | Armenia         | 0,2389 | Albania         | 0,0241 |
| 11 | Georgia         | 0,1437 | Georgia         | 0,0186 | Moldova         | 0,0115 |
| 12 | Armenia         | 0,0000 | Moldova         | 0,0000 | Armenia         | 0,0000 |

### **Conclusion, Discussion, and Recommendations**

The level of logistics performance is a crucial factor in enabling both developed contries and emerging economies to maintain the sustainable flow of goods and services in international trade and to adapt to global competition. In this regard, identifying the criteria that influence countries' logistics performance and analyzing these criteria based on their relative importance is of significant value for both decision-makers and researchers. The BSEC (Black Sea Economic Cooperation) member states, strategically located between Europe and Asia, possess globally significant ports and serve as central nodes for multimodal transport, energy corridors, and international trade routes.

Following the dissolution of the Soviet Union, many BSEC member countries underwent both political and economic transformations, which also necessitated the restructuring of their foreign trade systems and logistics infrastructure. Therefore, analyzing the logistics performance levels of BSEC countries based on objective data offers valuable insights that can strengthen regional integration and guide the development of sustainable logistics strategies.

Accordingly, this study evaluates the logistics performance levels of BSEC member states using an integrated Entropy-EDAS approach. Based on this methodological framework, the criteria influencing logistics performance were objectively weighted, and separate rankings for the years 2016, 2018, and 2023 were obtained for each BSEC country. The findings derived from these analyses facilitate the assessment of the countries' logistics priorities, strengths, and weaknesses, while also providing a foundation for policy recommendations.

The results obtained from the Entropy-based evaluation of the importance levels of the criteria indicate that timeliness emerges as a key factor in the logistics activities of BSEC countries. In particular, the fact that "Timeliness" had the highest weight in both 2016 and 2023 can be interpreted as a reflection of global supply chains increasingly focusing on time sensitivity in response to customer demands. The prominence of the Customs criterion in 2018 and 2023 highlights the increasing significance of customs procedures on logistics performance due to rising international trade barriers, regional integration challenges, and delays at border crossings. For countries such as Türkiye, Bulgaria, Romania, Ukraine, and Georgia, which serve as a bridge between Europe and Asia and accommodate multinational trade routes via land, sea, and rail, customs procedures constitute a fundamental determinant of both foreign trade volume and logistics efficiency.

In the post-2018 period, escalating tensions in Russia-Ukraine relations, the annexation of Crimea, and growing political instability in Eastern Europe have rendered customs processes more complex and time-consuming for BSEC countries. In particular, Russia's aggression toward Ukraine and the sanctions imposed by the European Union have led to stricter border

controls and more complicated customs procedures (European Parliament, 2022), thereby negatively affecting the reliability of the logistics chain.

Consequently, although BSEC countries maintain strong trade relations with both Europe and Eurasia, their political and economic heterogeneity imply that the efficiency of customs operations in certain regions plays a decisive role in overall logistics performance. Any disruptions at customs checkpoints can significantly increase costs, especially for the smaller and developing BSEC members, and contribute to greater fragility within their supply chains.

The infrastructure criterion consistently received relatively lower weight values compared to other criteria in the years 2016, 2018, and 2023. The BSEC countries occupy a strategically important transit zone between China-Europe railway projects (such as the Middle Corridor), the EU's Eastern European connection routes, and Russia's North-South transport axes. However, it can be stated that many of these corridors have not yet reached their full potential due to regional integration issues and ongoing political tensions, such as the Russia-Ukraine war and the Armenia-Azerbaijan conflict.

Therefore, although transportation corridors exist in the region, their limited operational integration and efficiency reduce the practical impact of the infrastructure criterion on overall logistics performance. In this context, one of the key priorities of BSEC is to enhance interregional trade and logistics activities, and to facilitate the cross-border movement of goods and people (Republic of Türkiye, Ministry of Foreign Affairs, 2025).

The findings derived from the EDAS-based analysis of the alternatives reveal that, within the BSEC region, Greece, Türkiye, and Romania demonstrated the highest levels of performance over the period 2016–2023. These results can be attributed to several factors, including their strategic geographical locations, investments in transportation and logistics infrastructure, levels of integration with the European Union, and relatively high trade volumes. Notably, Greece possesses one of the world's largest commercial shipping fleets. A significant contributor to its logistics advancement has been the large-scale investment in the Port of Piraeus as part of China's Belt and Road Initiative (BRI). The port has been modernized by COSCO, China's state-owned logistics giant (Yılmaz & Sabancı, 2021, p. 92). As a result, the Port of Piraeus has become a strategic transshipment hub for maritime trade between Europe and Asia (Güçyetmez & Kısacık, 2025, p. 916). Moreover, Greece is strategically positioned as a key transit point within the framework of the India-Middle East-Europe Economic Corridor (IMEC), serving as the main European gateway for cargo shipped via sea from the Port of Haifa. Through the Port of Piraeus, these goods are transported overland to various European destinations, positioning Greece as a strategic multimodal logistics hub on the European leg of the corridor (Özdemir & Çökerdenoğlu, 2024, p. 92). Greece is also integrated into the EU's common customs policies and digitalization initiatives, enabling it to demonstrate higher performance in criteria such as customs efficiency and timeliness, compared to other EU member states.

Türkiye, on the other hand, lies at the intersection of land, sea, air, and rail corridors that connect Europe and Asia. Functioning as a strategic logistics bridge between the two continents, Türkiye has, in recent years, undertaken numerous major projects aimed at strengthening its international logistics infrastructure. These initiatives have significantly enhanced Türkiye's role in global trade and provided substantial advantages in transit transport. For instance, the Baku-Tbilisi-Kars (BTK) Railway Line constitutes a critical segment of the Middle

Corridor, extending from China to Europe, and plays a pivotal role in linking Türkiye with Central Asia and the Caucasus region en route to Europe (Republic of Türkiye, Ministry of Trade, 2024). Additionally, the Trans-Anatolian Natural Gas Pipeline Project (TANAP), which transports natural gas from Azerbaijan to Europe via Türkiye, supports Türkiye's ambition to become a major energy corridor, while enhancing the country's energy supply security. TANAP thereby places Türkiye at the center of European energy logistics (Republic of Türkiye, Ministry of Energy and Natural Resources, 2025). In addition, the Zangezur Corridor stands out as a project aiming to establish a direct land and rail connection between Türkiye and Azerbaijan, thereby creating a new logistics route between Türkiye and Central Asia (Gasımova & Yurcu, 2023, p. 2). Beyond this, Türkiye's position as an emerging logistics hub is also reinforced by its Customs Union relationship with the European Union and its inclusion in the Trans-European Transport Network (TEN-T). In light of these developments, it can be stated that Türkiye's high ranking in logistics performance among BSEC countries is significantly driven by its strategic geographical location, robust infrastructure investments, and active involvement in international integration initiatives (TCDD, 2022). Romania has also advanced its infrastructure projects through EU transportation and logistics investment funds. Its location along the TRACECA (Transport Corridor Europe–Caucasus–Asia), which is considered a modern extension of the ancient Silk Road, enables Romania to offer one of the shortest, fastest, and potentially most cost-effective maritime transport links in the east–west direction (Çaylan, 2011, p. 93). The location of the Port of Constanța as a key export gateway for Romanian oil further enhances the country's port efficiency and strategic importance in the Black Sea region. In addition, Romania has received €985.3 million in funding for 42 projects under the CEF-Transport (Connecting Europe Facility – Transport) program (European Commission, 2020). These factors contribute to Romania's position as one of the top-performing BSEC countries in terms of logistics performance.

The findings also reveal that ongoing military conflicts, infrastructure destruction, and border security issues in countries such as Ukraine and Russia have negatively impacted their logistics performance. In fact, both countries dropped two places in the 2023 ranking compared to 2016, placing them at the bottom of the BSEC logistics performance list. This decline reflects the damaging impact of war on transportation infrastructure and the operational restrictions imposed in these regions. The lower rankings of Georgia, Moldova, and Armenia, on the other hand, can be attributed to their relatively limited foreign trade volumes and underdeveloped transport infrastructure compared to other member countries within the BSEC framework.

### ***Policy Recommendations***

The research findings indicate that the “Customs” criterion was among the most influential factors in 2018 and 2023 across BSEC countries. In this regard, it is recommended that digital customs systems be integrated among BSEC member states. Developing members should be encouraged to adopt electronic data interchange (EDI), blockchain-based customs inspection tools, and AI-supported digital solutions. Furthermore, harmonization processes with standards such as the EU Customs Code should be accelerated, and common customs procedures should be established. These measures would help minimize time and cost losses at border crossings.

The “Timeliness” criterion was identified as the most important factor throughout all evaluated years, highlighting the need for time-sensitive logistics systems in BSEC countries. In

this context, the development of digital coordination systems among logistics centers in the region should be prioritized. Additionally, potential disruptions at border gates, port entries and exits, and rail transit points should be addressed by improving operational speed and capacity at these strategic locations.

The persistently low weight of the “Infrastructure” criterion over the years reveals the operational inefficiencies of existing corridors. To mitigate this, resilient infrastructure projects capable of withstanding disasters, wars, and crises should be developed. This approach would help reduce vulnerabilities arising from conflicts such as the Russia–Ukraine war.

Moreover, the European Union’s development of an integrated logistics infrastructure model under the Trans-European Transport Network (TEN-T)—which includes 5G technologies, digital infrastructures, and environmentally friendly transport systems—serves as a valuable model for the BSEC region (TCDD, 2022). The TEN-T policy of installing electric vehicle charging stations every 60 kilometers and building alternative fuel infrastructure along its core and comprehensive networks underscores the need for similar sustainable transport strategies within BSEC countries.

Accordingly, the following strategic recommendations are proposed. First, low-carbon logistics corridors should be established across BSEC countries in order to promote environmentally sustainable trade and transport practices. In addition, the deployment of 5G-enabled intelligent transportation infrastructure is essential for enhancing connectivity, efficiency, and real-time data management in logistics operations. Finally, charging and refueling stations for alternative fuels—such as electricity, hydrogen, and LNG—should be integrated into national transportation networks to support the transition toward greener mobility solutions.

By implementing such strategies, the region’s transportation infrastructure will advance in terms of both environmental sustainability and digital integration. This will not only enhance the logistics compatibility between BSEC countries and the EU but also improve their competitiveness in Euro-Eurasian trade and significantly boost logistics performance levels.

#### ***Recommendations for Future Research***

In future studies, if new components are added to the index, these analyses can be updated accordingly for subsequent years, potentially yielding different and more comprehensive results. In particular, considering the bidirectional and dynamic interaction between international trade and logistics, the influence of foreign trade indicators on logistics performance in BSEC countries could be further explored through econometric analysis methods. In this context, incorporating variables such as import and export volumes, trade openness ratios, membership in regional trade agreements, and indicators of political and economic crises would enable a more comprehensive and policy-oriented evaluation of the logistics performance of the countries in question.

#### **REFERENCES**

- AYÇİN, E. (2020). *Çok kriterli karar verme bilgisayar uygulamalı çözümler*. Ankara: Nobel Akademik Yayıncılık.
- ÇALIK, A., ERDEBİLLİ, B., & ÖZDEMİR, Y. S. (2023). Novel integrated hybrid multi-criteria decision-making approach for logistics performance index. *Transportation Research Record*, 2677(2), 1392–1400. <https://doi.org/10.1177/03611981221113314>

- ÇATI, K., EŞ, A., & ÖZEVİN, O. (2017). Futbol Takımlarının Finansal ve Sportif Etkinliklerinin Entropi ve TOPSİS Yöntemiyle Analiz Edilmesi: Avrupa'nın 5 Büyük Ligi ve Süper Lig Üzerine Bir Uygulama. *International Journal of Management Economics and Business*, 13(1), 199-222. <https://doi.org/10.17130/ijmeb.20173126270>
- ÇAYLAN, D. Ö., & KİŞİ, H. (2011). Avrupa birliği ortak ulaştırma politikası ve Türkiye. *Dokuz Eylül Üniversitesi Denizcilik Fakültesi Dergisi*, 3(2), 79-100.
- ÇIRAY, D., ÖZDEMİR, Ü., & METE, S. (2024). An evaluation of the logistics performance index using the ENTROPY-based ORESTE method. *Journal of Transportation and Logistics*, 9(1), 68-82. <https://doi.org/10.26650/JTL.2024.1437070>
- DEĞERLİ ÇİFÇİ, B., & BAYCAN, T. (2023). Marine trade and analysis of the ports in the Black Sea economic cooperation region. *Southeast European and Black Sea Studies*, 23(1), 61-88.
- European Commission (2020). Connecting Europe Facility (CEF) – Transport grants 2014-2020. [https://ec.europa.eu/inea/sites/default/files/eu\\_investment\\_in\\_transport\\_in\\_romania.pdf](https://ec.europa.eu/inea/sites/default/files/eu_investment_in_transport_in_romania.pdf)
- European Parliament (2022). Russia's war on Ukraine: Implications for transport. [https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733536/EPRS\\_BRI\(2022\)733536\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733536/EPRS_BRI(2022)733536_EN.pdf)
- GASIMOVA, T., & YURCU, M. E. (2023). Zengezur Koridoru'nun Azerbaycan'ın dış ticaret ve lojistik faaliyetlerine olası etkilerinin SWOT analizi. *Dumlupınar Üniversitesi İİBF Dergisi*, 12(1), 1-15. <https://doi.org/10.58627/dpuibf.1309005>
- GELMEZ, E., GÜLEŞ, H. K., & ZERENLER, M. (2024). Evaluation of logistics performances of G20 countries using SD-based COPRAS and SAW methods. *Journal of Turkish Operations Management*, 8(2), 339-353. <https://doi.org/10.56554/jtom.1471209>
- GHORABAE, M. K., ZAVADSKAS, E. K., OLFAT, L., & TURSKIS, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica (Netherlands)*, 26(3), 435-451. <https://doi.org/10.3233/INF-2015-1070>
- GÖK KISA, C., & AYÇİN, E. (2019). OECD ülkelerinin lojistik performanslarının SWARA tabanlı EDAS yöntemi ile değerlendirilmesi. *Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 9(1), 301-325. <https://doi.org/10.18074/ckuibfd.500320>
- GÜÇYETMEZ, F., & KISACIK, S. (2025). Çin'in deniz taşımacılık koridorları çerçevesinde arktik ve Akdeniz geçitlerinin konumları hakkında bir karşılaştırma. *Gaziantep Üniversitesi Sosyal Bilimler Dergisi*, 24(2), 912-935. <https://doi.org/10.21547/jss.1574311>
- GÜRLER, H. E., ÖZÇALICI, M., & PAMUCAR, D. (2024). Determining criteria weights with genetic algorithms for multi-criteria decision making methods: The case of logistics performance index rankings of European Union countries. *Socio-Economic Planning Sciences*, 91, 101758. <https://doi.org/10.1016/j.seps.2023.101758>
- HWANG, C., & YOON, K. (1981). *Multiple attribute decision making: Methods and applications, A state of the art survey*. New York, ABD: Springer-Verlag.

- IŞIK, Ö., AYDIN, Y., & KOŞAROĞLU, Ş. M. (2020). The assessment of the logistics performance index of CEE countries with the new combination of SV and MABAC methods. *LogForum*, 16(4), 549–559. <https://doi.org/10.17270/J.LOG.2020.504>
- OĞUZ, S. (2023). Evaluation of customs, infrastructure and logistics services with multi-criteria decision-making methods: A comparative analysis for the top 10 countries in the Logistics Performance Index. *Journal of Management, Marketing and Logistics*, 10(4), 167–178. <https://doi.org/10.17261/Pressacademia.2023.1837>
- OĞUZ, S., ALKAN, G., & YILMAZ, B. (2019). Seçilmiş Asya ülkelerinin lojistik performanslarının TOPSIS yöntemi ile değerlendirilmesi. *IBAD Sosyal Bilimler Dergisi*, (Special Issue), 497–507. <https://doi.org/10.21733/ibad.613421>
- ÖZDEMİR, D., & ÇÖKERDENOĞLU, M. (2024). Stratejinin kalbi: Koridor savaşları. In A. T. Dikmen (Ed.), *Zengezur Koridoru: Türkiye-Azerbaycan-Nahçıvan ekonomik, dış ticaret ve lojistik bağlantıları* (pp. 85–92). Efe Akademi. <https://doi.org/10.59617/efepub20242312>
- ÖZEKENCİ, E. K. (2025). Evaluation of the logistics performance index of OECD countries based on hybrid MCDM methods. *Marmara Üniversitesi İktisadi ve İdari Bilimler Dergisi*, 47(1), 47–76. <https://doi.org/10.14780/muiibd.1469898>
- ÖZTÜRK, N. S. (2025). Doğu Avrupa ve Orta Asya ülkelerinde ulaştırma yatırımları, lojistik performans ve dış ticaret ilişkisi: Bir panel veri analizi. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 18(2), 721–735. <https://doi.org/10.25287/ohuiibf.1606878>
- PEHLİVAN, P., ASLAN, A. I., DAVID, S., & BACALUM, S. (2024). Determination of logistics performance of G20 countries using quantitative decision-making techniques. *Sustainability*, 16(5), 1852. <https://doi.org/10.3390/su16051852>
- POPA, A. (2017). Aspects of cooperation in the Black Sea area after the fall of USSR. *Acta Universitatis Danubius. Relationes Internationales*, 10(2), 161–170.
- Republic of Türkiye, Ministry of Energy and Natural Resources (2025). <https://enerji.gov.tr/neupgm-boru-hatlari-ve-projeleri>
- Republic of Türkiye, Ministry of Foreign Affairs (2025). Karadeniz Ekonomik İşbirliği (KEİ) - Örgütünün Dünü, Bugünü ve Geleceği. <https://www.mfa.gov.tr/karadeniz-ekonomik-isbirlici-kei---orgutunun-dunu-bugunu-ve-gelececi.tr.mfa>
- Republic of Türkiye, Ministry of Trade (2025). Dış Ticaret Lojistiği. Retrieved from: <https://ticaret.gov.tr/data/5b87bf9113b8761160fa1258/D%C4%B1%C5%9F%20Ticaret%20Lojisti%C4%9Fi%202024.pdf>
- STEVÍČ, Ž., ERSOY, N., BAŞAR, E. E., & BAYDAŞ, M. (2024). Addressing the global logistics performance index rankings with methodological insights and an innovative decision support framework. *Applied Sciences*, 14(22), 10334. <https://doi.org/10.3390/app142210334>
- TCDD (2022). Demiryolu Sektör Raporu. Retrieved from: <https://static.tcdd.gov.tr/webfiles/userfiles/files/istapor/2022sektor.pdf>

- TÜRKÖĞLU, M., & DURAN, G. (2023). Çok kriterli karar verme yöntemleri ile Bölgesel Kapsamlı Ekonomik Ortaklık (RCEP) ülkelerinin lojistik performanslarının değerlendirilmesi. *Ekonomi Bilimleri Dergisi*, 15(1), 45–69. <https://doi.org/10.55827/ebd.1247297>
- ULUTAŞ, A., & KARAKÖY, Ç. (2019). An analysis of the logistics performance index of EU countries with an integrated MCDM model. *Economics and Business Review*, 5(4), 49–69. <https://doi.org/10.18559/ebr.2019.4.3>
- World Bank (2023). Logistics Performance Index. Retrieved from: <https://lpi.worldbank.org/> (Date accessed: 07.05.2025).
- YILMAZ, B. (2025). Determining the digitalization levels of leading countries in logistics performance index: An application with CRITIC-TOPSIS approach. *Verimlilik Dergisi*, 59(2), 433–452. <https://doi.org/10.51551/verimlilik.1541480>
- YILMAZ, Z., & SABANCI, B. (2021). Bir Kuşak-Bir Yol projesi kapsamında Akdeniz ticaret limanlarında Türkiye fırsatları. *Ekonomi Maliye İşletme Dergisi*, 4(1), 87-100. <https://doi.org/10.46737/emid.938391>