Marmara Üniversitesi İktisadi ve İdari Bilimler Dergisi • Cilt: 47 • Sayı: 1 2025, ISSN: 2587-2672, ss/pp. 47-76
DOI: 10.14780/muiibd.1469898

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

EVALUATION OF THE LOGISTICS PERFORMANCE INDEX OF OECD COUNTRIES BASED ON HYBRID MCDM METHODS

OECD ÜLKELERİNİN LOJİSTİK PERFORMANS ENDEKSİNİN HİBRİT ÇKKV YÖNTEMLERİNE GÖRE DEĞERLENDİRİLMESİ

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Abstract

This study aims to assess the logistics performance index (LPI) of OECD countries using integrated multi-criteria decision-making (MCDM) methods. The data was obtained from the "*Connecting to Compete 2023 – LPI*" report. Initially, the weight of the criteria was determined using several methods, including SD, CRITIC, LOPCOW, and MEREC. Then, criteria weights obtained from different methods were combined with the Aggregate Weighting Method (AWM). The LPI of OECD countries were ranked using the CRADIS method. The results of the AWM showed that tracking and tracing, as well as logistics competence and quality, were the most and least important criteria, respectively. The results of the CRADIS method revealed that Finland had the best logistics performance, while Costa Rica had the worst logistics performance among OECD countries. Additionally, the robustness and validity of the proposed model were tested by sensitivity analysis and comparative analysis.

Keywords: LPI, OECD, MCDM
JEL Classification: C60, F14, L91

Öz

Bu çalışma, entegre MCDM yöntemlerini kullanarak OECD ülkelerinin lojistik performans endeksini (LPI) değerlendirmeyi amaçlamaktadır. Bu çalışma için veriler "*Rekabete Bağlanmak 2023 – LPI*" raporundan elde edilmiştir. İlk olarak, kriterlerin ağırlıkları SD, CRITIC, LOPCOW ve MEREC gibi çeşitli yöntemlerle belirlenmiştir. Daha sonra, farklı yöntemlerden elde edilen kriter ağırlıkları, Toplu Ağırlıklandırma Yöntemi (AWM) ile birleştirilmiştir. OECD ülkelerinin LPI'leri CRADIS yöntemi kullanılarak sıralanmıştır. AWM sonuçları, izleme ve takip ile lojistik yeterliliği ve kalitenin sırasıyla en önemli ve en az önemli kriterler

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How to cite this article/Atıf için: Özekenci EK. (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. DOI: 10.14780/muiibd.1469898

Makale Gönderim Tarihi: 17.04.2024 **Yayına Kabul Tarihi:** 11.02.2025 **Benzerlik Oranı:** %17

olduğunu göstermiştir. CRADIS yönteminin sonuçları Finlandiya'nın OECD ülkeleri arasında en iyi lojistik performansına sahip ülke olduğunu, Kosta Rika'nın ise en kötü lojistik performansına sahip olduğunu ortaya koymuştur. Buna ilaveten, önerilen modelin sağlamlığı ve geçerliliği duyarlılık analizi ve karşılaştırmalı analizle test edilmiştir.
Anahtar Kelimeler: LPI, OECD, ÇKKV
JEL Sınıflandırması: C60, F14, L91

1. Introduction

Over the last few decades, international trade has been significantly accelerated by the help of globalization, rapid development in information technology, and the increasing number of free trade agreements between countries. In the previous period of globalization, countries primarily focused on regional competition. However, globalization has expanded the field to almost every country in the world, increasing the importance of logistics in global trade and making it a fundamental component of national development (Marti et al., 2014; Rezaei et al., 2018). The increasing importance of global economic integration and the globalization of economies contribute to the development of global supply chains and international logistics systems on the international market (Beysenbaev & Dus, 2020). Rashidi and Cullinane (2019) stated that the logistics sector also makes a substantial contribution to the enhancing performance of the national economy. Additionally, it plays a crucial role in social and environmental aspects. This necessitated the development of strategies to enhance national performance, as well as a specific framework for measuring logistics performance (Göçer et al., 2022).

The LPI is a survey-based index published by the World Bank since 2007, and it's widely used in a global context (the 2023 version includes 139 countries) to reveal differences in logistics activities between nations. The LPI has been analyzed through six indicators, namely customs, infrastructure, international shipments, logistics competence and quality, timeliness, and tracking and tracing. These indicators were selected based on theoretical and empirical research, as well as the practical experience of logistics professionals involved in international freight forwarding (Arvis et al., 2023). According to Gogoneata (2008), the LPI is an effective tool that helps measure and evaluate nations' logistics performance on a global scale, identify areas for improvement, and determine logistics challenges. Thus, countries can analyze their current potential and performance regarding logistics operations and create specific strategies to improve their weaknesses. Since many criteria, alternatives, and expert opinions are examined for measuring the LPI, the evaluation of the LPI can be expressed as a complex problem. Parallel to this, several MCDM methods have been applied to analyze the logistics performance of countries so far (Martí et al., 2017; Yıldırım & Adıgüzel Mercangöz, 2020; Biswas & Anand, 2020; Çalık et al., 2023; Gürler et al., 2024).

Accordingly, this paper aims to examine the LPI of OECD countries using the integrated MCDM methods. For this investigation, various objective weighting methods, namely SD, CRITIC, LOPCOW, and MEREC, were used to determine the weight of the criteria. Once the weight of each criterion was determined by each method individually, the criterion weights were combined with the AWM. The CRADIS method was used to rank alternatives based on their logistics performance. Additionally,

the sensitivity and comparative analysis were conducted to ensure the reliability of the proposed model. To the best of the author's knowledge, this is the first study that evaluates the LPI of OECD countries using the SD, CRITIC, LOPCOW, and MEREC-based CRADIS methods. Additionally, it is essential to disclose the current state of global logistics operations, particularly in the aftermath of the COVID-19 pandemic and the Russia-Ukraine war. Therefore, it can be concluded that the findings obtained from this study will contribute to the existing literature not only by providing a new model but also by offering insight into the logistics performance of OECD countries for policy and decision-makers.

The remainder of the paper is structured as follows: Section 2 presents a brief overview of previous research in relevant fields. Section three describes the methodologies used for this study. The fourth section presents the research findings. The final section demonstrates a summary and critique of the findings, limitations, and recommendations for future research into this area.

2. Literature Review

In this section, the previous research on logistics performance is presented. In recent years, the number of research on evaluating the logistics performance of countries has increased significantly. Table 1 illustrates a brief synopsis of the relevant literature.

Table 1: Previous Research on Logistics Performance

Author(s)	Year	Methods	Topic
Çakır	2017	CRITIC-SAW-Peters' fuzzy	Measuring the logistics performance index of OECD countries
Orhan	2019	ENTROPY-EDAS	Comparison of the logistics performance index between Turkey and EU countries
Oğuz et al.	2019	TOPSIS	Investigation of the logistics performance index of selected Asian countries
Ulutaş & Karaköy	2019a	SD-WASPAS	Examining the logistics performance index of G20 countries
Ulutaş & Karaköy	2019b	SWARA-CRITIC-PIV	Assessment of the logistics performance index of European Union (EU) countries
Gök Kısa & Ayçin	2019	SWARA-EDAS	Evaluation of the logistics performance index of OECD countries
Yıldırım & Adıgüzel Mercangöz	2020	Fuzzy AHP (FAHP) – ARAS-G	Investigation of the logistics performance index of OECD countries
Isik et al.	2020	SV-MABAC	Examining the logistics performance index of Central and Eastern European (CEE) countries
Yalçın & Ayvaz	2020	FAPH-Fuzzy TOPSIS	Analyzing the logistics performance index of selected countries
Arıkan Kargı	2022	ENTROPY-WASPAS	Measurement of the logistics performance index of OECD countries
Mešić et al.	2022	CRITIC-MARCOS	Evaluation of the logistics performance index of the Western Balkan countries

Kara et al.	2022	ENTROPY-MABAC	Investigation of the logistics market performance of developing countries
Miškić et al.	2023	MEREC-MARCOS	Assessment of the logistics performance index of the EU countries
Özekenci	2023	SWARA-CRITIC-CoCoSo	Analyzing the logistics market performance of developing countries
Çalık et al.	2023	AHP-FAHP-PFAHP-TOPSIS VIKOR-CODAS	Examining the logistics performance index of OECD countries
Özbek & Özekenci	2023	LOPCOW-MAUT-TOPSIS-MARCOS-CoCoSo	Evaluation of the digital logistics market performance of developing countries
Gürler et al.	2024	CRITIC-ENTROPY-ARAS-CoCoSo-CODAS-COPRAS-EDAS-GREY-MABAC-MARCOS-MOORA-OCRA-WASPAS	Assessment of the logistics performance index of EU countries
Özekenci	2024	ENTROPY-CRITIC-LOPCOW-EDAS	Analyzing the logistics performance index of OPEC countries

As shown above, a substantial number of studies have been published that evaluate the logistics performance index of countries using various MCDM methods. Although extensive research has been conducted on logistics performance using hybrid MCDM methods, no single study has been found that evaluates the logistics performance of OECD countries using SD, CRITIC, LOPCOW, and MEREC-based CRADIS methods. Thus, this study aims to contribute to the existing literature by proposing a new MCDM model.

3. Methodology

This paper investigates the logistics performance index of OECD countries using the integrated SD, CRITIC, LOPCOW, MEREC-based CRADIS model. The application steps of each method are described separately below.

3.1. SD Method

The standard deviation (SD) method was proposed by Rao and Patel in 2010. It is one of the most popular methods among the objective weighting approaches. The SD method is widely used to determine the weight of criteria, and its application steps are as follows (Rao & Patel, 2010; Rao et al., 2011; Yürüyen et al., 2023):

Step 1. The decision matrix is formed.

Step 2. The decision matrix is normalized based on Equation (1).

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

Step 3. Equation (2) is used to calculation of standard deviation (σ) for each criterion.

$$V_j = \left(\frac{1}{n}\right)\sum_{i=1}^{n}(a_{ij}^{*} - \bar{a}_{ij}^{*})^2 \tag{2}$$

Step 4. The weight of criteria is determined by Equation (3).

$$W_{jSV} = \frac{V_j}{\sum_{i=1}^{m} V_j} \tag{3}$$

3.2. CRITIC Method

The Criteria Importance Through Intercriteria Correlation (CRITIC) method was proposed by Diakoulaki et al. in 1995. It's one of the well-known objective weighting methods, and its application steps are as follows (Diakoulaki et al., 1995):

Step 1. Firstly, an initial decision matrix is formed.

Step 2. Then, the decision matrix is normalized using Eqs. (4-5).

$$x_{ij} = \frac{r_{ij} - r_i^{-}}{r_i^{t} - r_i^{-}}; \tag{4}$$

$$x_{ij} = \frac{r_{ij} - r_i^{+}}{r_i^{-} - r_i^{+}}; \tag{5}$$

Step 3. Eqs. (6-7) is used to determine the correlation coefficient among attributes.

$$\sqrt{\sum_{i=1}^{m}\left(x_{ij} - \bar{x}_j\right)^2 \sum_{i=1}^{m}(x_{ik} - \bar{x}_k)^2} \tag{6}$$

$$\bar{x}_j = \frac{1}{n}\sum_{j=1}^{n} x_{ij}; \tag{7}$$

Step 4. At first, the standard deviation of each attribute is estimated by Equation (8).

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(x_{ij} - \bar{x}_j\right)^2}; \qquad i = 1, \ldots\ldots\ldots\ldots\ldots, n \tag{8}$$

Then, the index (C) is calculated using Equation (9).

$$C_J = \sigma_j \sum_{k=1}^{n} (1 - \rho_{jk}); \tag{9}$$

Step 5. The weights of the attributes are determined by Equation (10).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j}; \qquad j = 1, \dots\dots\dots\dots\dots, n \tag{10}$$

For the final ranking, the attribute weights are ranked in descending order.

3.3. LOPCOW Method

The Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) method was developed by Ecer and Pamucar in 2022. It has recently been proposed as one of the new objective weighting methods. The application steps of the LOPCOW method are as follows (Ecer & Pamucar, 2022):

Step 1. The decision matrix is formed.

Step 2. According to Eqs. (11-12), the decision matrix is normalized.

$$r_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}, \text{ if } j \text{ is a cost criterion} \tag{11}$$

$$r_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}, \text{ if } j \text{ is a benefit criterion} \tag{12}$$

Step 3. Percentage values (PV) of each criterion are determined based on Equation (13).

$$PV_{ij} = \left| \ln \left(\frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^2}{m}}}{\sigma} \right) . 100 \right| \tag{13}$$

Step 4. Calculate the weights of the criteria using Equation (14).

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \tag{14}$$

3.4. MEREC Method

The method based on the Removal Effects of Criteria (MEREC) method was developed by Keshavarz-Ghorabaee et al. in 2021. It's one of the recently proposed objective weighting methods for determining the weight of criteria. The application steps of the MEREC method are as follows (Keshavarz-Ghorabaee et al., 2021):

Step 1. The decision matrix is constructed.

Step 2. The decision matrix is normalized based on Eqs. (15-16).

$$N_{ij} = \left\{ \frac{min_{x_{kj}}}{x_{ij}} \right\} \; if \; j \in B \tag{15}$$

$$N_{ij} = \left\{ \frac{x_{ij}}{max_{x_{kj}}} \right\} \; if \; j \in B \tag{16}$$

Step 3. The overall performance of the alternatives (S_i) is calculated using Equation (17).

$$N_{ij}S_i = \ln\left(1 + \left(\frac{1}{m}\sum_j \left|\ln(N_{ij}\right|\right)\right) \tag{17}$$

Step 4. According to Equation (18), the performance of the alternatives is computed by removing each criterion.

$$S'_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} \left|\ln(N_{ij}\right|\right)\right) \tag{18}$$

Step 5. The summation of absolute deviations is calculated using Equation (19).

$$E_j = \sum_i \left|S'_{ij} - S_i\right| \tag{19}$$

Step 6. The final weights of criteria are determined based on Equation (20).

$$w_i = \frac{E_i}{\sum_K E_k} \tag{20}$$

3.5. AWM

Equation (21) is used to determine the aggregated weights of criteria.

$$W_{Aggregated} = \frac{W_{JSD} + W_{JCRITIC} + W_{JMEREC} + W_{JLOPCOW}}{4} \tag{21}$$

3.6. CRADIS Method

The compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) method was proposed by Puška et al. in 2021. This method combines various MCDM techniques, including ARAS, MARCOS, and TOPSIS. The application steps of the CRADIS method are shown below (Puška et al., 2021):

Step 1. The decision matrix is created.

Step 2. The decision matrix is normalized using Eqs. (22-23).

$$n_{ij} = \frac{x_{ij}}{x_{jmax}} \tag{22}$$

$$n_{ij} = \frac{x_{jmin}}{x_{ij}} \tag{23}$$

Step 3. Based on Equation (24), the aggravated decision matrix is obtained.

$$v_{ij} = n_{ij} \,.\, w_j \tag{24}$$

Step 4. The ideal and anti-ideal solution is determined according to Eqs. (25-26).

$$t_i = max v_{ij} \tag{25}$$

$$t_{ai} = min v_{ij} \tag{26}$$

Step 5. The deviations from ideal and anti-ideal solutions are computed using Eqs. (27-28).

$$d^+ = t_i - v_{ij} \tag{27}$$

$$d^- = v_{ij} - t_{ai} \tag{28}$$

Step 6. According to Eqs. (29-30), the grades of the deviation of individual alternatives from ideal and anti-ideal solutions are determined.

$$s_i^+ = \sum_{j=1}^{n} d^+ \tag{29}$$

$$s_i^- = \sum_{j=1}^{n} d^- \tag{30}$$

Step 7. Based on Eqs. (31-32), the utility function for each alternative is calculated.

$$K_i^+ = \frac{s_0^+}{s_i^+} \tag{31}$$

$$K_i^- = \frac{s_i^-}{s_0^-} \tag{32}$$

Step 8. The final order is obtained using Equation (33).

$$Q_i = \frac{K_i^+ + K_i^+}{2} \tag{33}$$

The best alternative is the one that has the most significant value Q_i

4. Results

According to the World Bank, the LPI of countries is assessed based on six indicators: customs, infrastructure, international shipments, logistics competence and quality, timeliness, and tracking and tracing (Arvis et al., 2023). The World Bank periodically publishes reports measuring the logistics performance of countries according to these indicators. For this investigation, the data was obtained from the "*Connecting to Compete 2023 – LPI*" report. In this study, the LPI of a total of thirty-eight economies was examined. These countries are as follows: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom and United States. A brief explanation of the criteria used in this study is demonstrated in Table 2.

Table 2: An Overview of Criteria

No	Criterion	Abbr.	Definition
1	Customs	C_1	The efficiency of customs and border management clearance.
2	Infrastructure	C_2	The quality of trade – and transport-related infrastructure.
3	International Shipments	C_3	The ease of arranging competitively priced international shipments.
4	Logistics competence & Quality	C_4	The competence and quality of logistics services
5	Timeliness	C_5	The ability to track and trace consignments
6	Tracking & Tracing	C_6	The frequency with which shipments reach consignees within the scheduled or expected delivery time.

Source: Arvis et al. (2023)

As mentioned above, the current study aims to evaluate the LPI of OECD countries using the integrated MCDM methods. In this study, the weight of criteria was determined using more than one objective weighting method, such as SD, CRITIC, LOPCOW, and MEREC. Once the weight of the

criteria was calculated, the alternatives were ranked by the CRADIS method. Subsequently, sensitivity and correlation analyses were conducted to assess the validity and robustness of the results. Table 3 presents the decision matrix for OECD countries based on data from the LPI 2023 report.

Table 3: Decision Matrix

No	Economy	C_1	C_2	C_3	C_4	C_5	C_6
		max	max	max	max	max	max
1	Australia	3.70	4.10	3.10	3.90	4.10	3.60
2	Austria	3.70	3.90	3.80	4.00	4.20	4.30
3	Belgium	3.90	4.10	3.80	4.20	4.00	4.20
4	Canada	4.00	4.30	3.60	4.20	4.10	4.10
5	Chile	3.00	2.80	2.70	3.10	3.00	3.20
6	Colombia	2.50	2.90	3.00	3.10	3.10	3.20
7	Costa Rica	2.80	2.70	2.80	2.90	2.90	3.20
8	Czech Republic	3.00	3.00	3.40	3.60	3.20	3.70
9	Denmark	4.10	4.10	3.60	4.10	4.30	4.10
10	Estonia	3.20	3.50	3.40	3.70	3.80	4.10
11	Finland	4.00	4.20	4.10	4.20	4.20	4.30
12	France	3.70	3.80	3.70	3.80	4.00	4.10
13	Germany	3.90	4.30	3.70	4.20	4.20	4.10
14	Greece	3.20	3.70	3.80	3.80	3.90	3.90
15	Hungary	2.70	3.10	3.40	3.10	3.40	3.60
16	Iceland	3.70	3.60	3.30	3.50	3.70	3.60
17	Ireland	3.40	3.50	3.60	3.60	3.70	3.70
18	Israel	3.40	3.70	3.50	3.80	3.70	3.80
19	Italy	3.40	3.80	3.40	3.80	3.90	3.90
20	Japan	3.90	4.20	3.30	4.10	4.00	4.00
21	Korea	3.90	4.10	3.40	3.80	3.80	3.80
22	Latvia	3.30	3.30	3.20	3.70	3.60	4.00
23	Lithuania	3.20	3.50	3.40	3.60	3.10	3.60
24	Luxembourg	3.60	3.60	3.60	3.90	3.50	3.50
25	Mexico	2.50	2.80	2.80	3.00	3.10	3.50
26	Netherlands	3.90	4.20	3.70	4.20	4.20	4.00
27	New Zealand	3.40	3.80	3.20	3.70	3.80	3.80
28	Norway	3.80	3.90	3.00	3.80	3.70	4.00
29	Poland	3.40	3.50	3.30	3.60	3.80	3.90
30	Portugal	3.20	3.60	3.10	3.60	3.20	3.60
31	Slovak Republic	3.20	3.30	3.00	3.40	3.30	3.50
32	Slovenia	3.40	3.60	3.40	3.30	3.00	3.30
33	Spain	3.60	3.80	3.70	3.90	4.10	4.20
34	Sweden	4.00	4.20	3.40	4.20	4.10	4.20
35	Switzerland	4.10	4.40	3.60	4.30	4.20	4.20
36	Türkiye	3.00	3.40	3.40	3.50	3.50	3.60
37	United Kingdom	3.50	3.70	3.50	3.70	4.00	3.70
38	United States	3.70	3.90	3.40	3.90	4.20	3.80

Since all criteria used in this study are considered beneficial, therefore equations related to cost criteria are not included in the proposed model. The following section presents the results obtained from the proposed model.

4.1. The Results Obtained from the SD Method

Based on Equation (1), the decision matrix was normalized. Since the same normalization process is applied in the SD, CRITIC, and LOPCOW methods, a single normalization decision matrix was formed (Table 4). Eqs. (2-3) was used to calculate the standard deviation (σ) and the weight of criteria (W_j). The results obtained from the SD method are presented below.

Table 4: Normalized Decision Matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,7500	0,8235	0,2857	0,7143	0,8571	0,3636
Austria	0,7500	0,7059	0,7857	0,7857	0,9286	1,0000
Belgium	0,8750	0,8235	0,7857	0,9286	0,7857	0,9091
Canada	0,9375	0,9412	0,6429	0,9286	0,8571	0,8182
Chile	0,3125	0,0588	0,0000	0,1429	0,0714	0,0000
Colombia	0,0000	0,1176	0,2143	0,1429	0,1429	0,0000
Costa Rica	0,1875	0,0000	0,0714	0,0000	0,0000	0,0000
Czech Republic	0,3125	0,1765	0,5000	0,5000	0,2143	0,4545
Denmark	1,0000	0,8235	0,6429	0,8571	1,0000	0,8182
Estonia	0,4375	0,4706	0,5000	0,5714	0,6429	0,8182
Finland	0,9375	0,8824	1,0000	0,9286	0,9286	1,0000
France	0,7500	0,6471	0,7143	0,6429	0,7857	0,8182
Germany	0,8750	0,9412	0,7143	0,9286	0,9286	0,8182
Greece	0,4375	0,5882	0,7857	0,6429	0,7143	0,6364
Hungary	0,1250	0,2353	0,5000	0,1429	0,3571	0,3636
Iceland	0,7500	0,5294	0,4286	0,4286	0,5714	0,3636
Ireland	0,5625	0,4706	0,6429	0,5000	0,5714	0,4545
Israel	0,5625	0,5882	0,5714	0,6429	0,5714	0,5455
Italy	0,5625	0,6471	0,5000	0,6429	0,7143	0,6364
Japan	0,8750	0,8824	0,4286	0,8571	0,7857	0,7273
Korea	0,8750	0,8235	0,5000	0,6429	0,6429	0,5455
Latvia	0,5000	0,3529	0,3571	0,5714	0,5000	0,7273
Lithuania	0,4375	0,4706	0,5000	0,5000	0,1429	0,3636
Luxembourg	0,6875	0,5294	0,6429	0,7143	0,4286	0,2727
Mexico	0,0000	0,0588	0,0714	0,0714	0,1429	0,2727
Netherlands	0,8750	0,8824	0,7143	0,9286	0,9286	0,7273
New Zealand	0,5625	0,6471	0,3571	0,5714	0,6429	0,5455
Norway	0,8125	0,7059	0,2143	0,6429	0,5714	0,7273
Poland	0,5625	0,4706	0,4286	0,5000	0,6429	0,6364
Portugal	0,4375	0,5294	0,2857	0,5000	0,2143	0,3636
Slovak Republic	0,4375	0,3529	0,2143	0,3571	0,2857	0,2727

Slovenia	0,5625	0,5294	0,5000	0,2857	0,0714	0,0909
Spain	0,6875	0,6471	0,7143	0,7143	0,8571	0,9091
Sweden	0,9375	0,8824	0,5000	0,9286	0,8571	0,9091
Switzerland	1,0000	1,0000	0,6429	1,0000	0,9286	0,9091
Türkiye	0,3125	0,4118	0,5000	0,4286	0,4286	0,3636
United Kingdom	0,6250	0,5882	0,5714	0,5714	0,7857	0,4545
United States	0,7500	0,7059	0,5000	0,7143	0,9286	0,5455
σ	0,2714	0,2686	0,2206	0,2637	0,2992	0,2853
W_j	0,1687	0,1670	0,1371	0,1639	0,1860	0,1773
Rank	3	4	6	5	1	2

The results of the SD method showed that C_5 (timeliness) and C_3 (international shipments) were the most and least important criteria, respectively. Additionally, the general ranking of criteria was determined as follows: $C_5 > C_6 > C_1 > C_2 > C_4 > C_3$.

4.2. The Results Obtained from the CRITIC Method

Eqs. (6–7) were used to determine the correlation coefficient of the criteria, and their results are presented in Table 5.

Table 5: Correlation Coefficient

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1,0000	0,9307	0,5918	0,8977	0,8154	0,7228
C_2	0,9307	1,0000	0,6473	0,9301	0,8587	0,7542
C_3	0,5918	0,6473	1,0000	0,7190	0,6836	0,7059
C_4	0,8977	0,9301	0,7190	1,0000	0,8718	0,8456
C_5	0,8154	0,8587	0,6836	0,8718	1,0000	0,8464
C_6	0,7228	0,7542	0,7059	0,8456	0,8464	1,0000

According to Eqs. (8-9), the standard deviation of each attribute and the index (C) were calculated, and its results are shown in Table 6.

Table 6: The Index (C)

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
C_1	0,0000	0,0693	0,4082	0,1023	0,1846	0,2772
C_2	0,0693	0,0000	0,3527	0,0699	0,1413	0,2458
C_3	0,4082	0,3527	0,0000	0,2810	0,3164	0,2941
C_4	0,1023	0,0699	0,2810	0,0000	0,1282	0,1544
C_5	0,1846	0,1413	0,3164	0,1282	0,0000	0,1536
C_6	0,2772	0,2458	0,2941	0,1544	0,1536	0,0000
Total	1,0416	0,8790	1,6525	0,7358	0,9242	1,1252

Equation (10) was used to determine the weight of the criteria, and the final ranking of the criteria is presented in Table 7.

Table 7: Results of the CRITIC Method

	C_1	C_2	C_3	C_4	C_5	C_6
C_j	0,2827	0,2361	0,3646	0,1940	0,2766	0,3210
W_j	0,1688	0,1410	0,2177	0,1158	0,1651	0,1916
Rank	3	5	1	6	4	2

The results of the CRITIC method showed that C_3 (international shipments) and C_4 (logistics competence and quality) were the most and least important criteria, respectively. Moreover, the general ranking of criteria was determined as follows: $C_3 > C_6 > C_1 > C_5 > C_2 > C_4$.

4.3. The Results Obtained from the LOPCOW Method

Eqs. (13–14) were used to determine the percentage values (*PV*) of each criterion and the weight of the criteria, respectively. The results obtained from the LOPCOW method are shown in Table 8.

Table 8: Results of the LOPCOW Method

	C_1	C_2	C_3	C_4	C_5	C_6
Mean Square	0,6069	0,5774	0,4981	0,5940	0,5902	0,5574
σ	0,2714	0,2686	0,2206	0,2637	0,2992	0,2853
PV	80,4692	76,5146	81,4406	81,2118	67,9266	66,9865
W_j	0,1770	0,1683	0,1792	0,1787	0,1494	0,1474
Rank	3	4	1	2	5	6

The results of the LOPCOW method showed that C_3 (international shipments) and C_6 (tracking and tracing) were most and least important criteria, respectively. Furthermore, the general ranking of criteria was determined as follows: $C_3 > C_4 > C_1 > C_2 > C_5 > C_6$.

4.4. The Results Obtained from the MEREC Method

The decision matrix was normalized using Equation (15) and is presented in Table 9.

Table 9: Normalized-Decision Matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,6757	0,6585	0,8710	0,7436	0,7073	0,8889
Austria	0,6757	0,6923	0,7105	0,7250	0,6905	0,7442
Belgium	0,6410	0,6585	0,7105	0,6905	0,7250	0,7619
Canada	0,6250	0,6279	0,7500	0,6905	0,7073	0,7805
Chile	0,8333	0,9643	1,0000	0,9355	0,9667	1,0000
Colombia	1,0000	0,9310	0,9000	0,9355	0,9355	1,0000
Costa Rica	0,8929	1,0000	0,9643	1,0000	1,0000	1,0000
Czech Republic	0,8333	0,9000	0,7941	0,8056	0,9063	0,8649
Denmark	0,6098	0,6585	0,7500	0,7073	0,6744	0,7805
Estonia	0,7813	0,7714	0,7941	0,7838	0,7632	0,7805
Finland	0,6250	0,6429	0,6585	0,6905	0,6905	0,7442
France	0,6757	0,7105	0,7297	0,7632	0,7250	0,7805
Germany	0,6410	0,6279	0,7297	0,6905	0,6905	0,7805
Greece	0,7813	0,7297	0,7105	0,7632	0,7436	0,8205

Hungary	0,9259	0,8710	0,7941	0,9355	0,8529	0,8889
Iceland	0,6757	0,7500	0,8182	0,8286	0,7838	0,8889
Ireland	0,7353	0,7714	0,7500	0,8056	0,7838	0,8649
Israel	0,7353	0,7297	0,7714	0,7632	0,7838	0,8421
Italy	0,7353	0,7105	0,7941	0,7632	0,7436	0,8205
Japan	0,6410	0,6429	0,8182	0,7073	0,7250	0,8000
Korea	0,6410	0,6585	0,7941	0,7632	0,7632	0,8421
Latvia	0,7576	0,8182	0,8438	0,7838	0,8056	0,8000
Lithuania	0,7813	0,7714	0,7941	0,8056	0,9355	0,8889
Luxembourg	0,6944	0,7500	0,7500	0,7436	0,8286	0,9143
Mexico	1,0000	0,9643	0,9643	0,9667	0,9355	0,9143
Netherlands	0,6410	0,6429	0,7297	0,6905	0,6905	0,8000
New Zeeland	0,7353	0,7105	0,8438	0,7838	0,7632	0,8421
Norway	0,6579	0,6923	0,9000	0,7632	0,7838	0,8000
Poland	0,7353	0,7714	0,8182	0,8056	0,7632	0,8205
Portugal	0,7813	0,7500	0,8710	0,8056	0,9063	0,8889
Slovak Republic	0,7813	0,8182	0,9000	0,8529	0,8788	0,9143
Slovenia	0,7353	0,7500	0,7941	0,8788	0,9667	0,9697
Spain	0,6944	0,7105	0,7297	0,7436	0,7073	0,7619
Sweden	0,6250	0,6429	0,7941	0,6905	0,7073	0,7619
Switzerland	0,6098	0,6136	0,7500	0,6744	0,6905	0,7619
Türkiye	0,8333	0,7941	0,7941	0,8286	0,8286	0,8889
United Kingdom	0,7143	0,7297	0,7714	0,7838	0,7250	0,8649
United States	0,6757	0,6923	0,7941	0,7436	0,6905	0,8421

According to Equation (17), the overall performance of the alternatives (S_i) was computed, and its results are presented in Table 10.

Table 10: S_i Values

Economy	S_i	Economy	S_i
Australia	0,0137	Japan	0,0118
Austria	0,0510	Korea	0,0162
Belgium	0,0486	Latvia	0,0404
Canada	0,0374	Lithuania	0,0216
Chile	0,1075	Luxembourg	0,0359
Colombia	0,1088	Mexico	0,1164
Costa Rica	0,1325	Netherlands	0,0422
Czech Republic	0,0053	New Zealand	0,0205
Denmark	0,0526	Norway	0,0379
Estonia	0,0039	Poland	0,0298
Finland	0,0712	Portugal	0,0163
France	0,0290	Slovak Republic	0,0121
Germany	0,0416	Slovenia	0,0032
Greece	0,0033	Spain	0,0358
Hungary	0,0356	Sweden	0,0350
Iceland	0,0584	Switzerland	0,0475
Ireland	0,0272	Türkiye	0,0215
Israel	0,0101	United Kingdom	0,0102
Italy	0,0018	United States	0,0131

Based on Equation (18), the performance of the alternatives was computed by removing each criterion, and the results are shown in Table 11.

Table 11: S'_{ij} Values

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,0503	0,0462	0,0361	0,0612	0,0575	0,0535
Austria	0,0129	0,0169	0,0127	0,0094	0,0174	0,0124
Belgium	0,0240	0,0284	0,0160	0,0207	0,0127	0,0206
Canada	0,0395	0,0402	0,0113	0,0249	0,0210	0,0331
Chile	0,1344	0,1129	0,1075	0,1174	0,1125	0,0006
Colombia	0,1088	0,1194	0,1245	0,1187	0,1187	0,0056
Costa Rica	0,1489	0,1325	0,1378	0,1325	0,1325	0,0060
Czech Republic	0,0351	0,0226	0,0428	0,0405	0,0215	0,0012
Denmark	0,0280	0,0404	0,0194	0,0289	0,0366	0,0292
Estonia	0,0366	0,0345	0,0392	0,0371	0,0328	0,0092
Finland	0,0046	0,0092	0,0053	0,0119	0,0119	0,0040
France	0,0353	0,0433	0,0390	0,0318	0,0401	0,0129
Germany	0,0312	0,0278	0,0032	0,0123	0,0123	0,0247
Greece	0,0372	0,0262	0,0305	0,0189	0,0231	0,0001
Hungary	0,0479	0,0576	0,0720	0,0463	0,0609	0,0000
Iceland	0,0052	0,0223	0,0364	0,0384	0,0295	0,0235
Ireland	0,0234	0,0312	0,0266	0,0382	0,0338	0,0001
Israel	0,0402	0,0390	0,0479	0,0462	0,0495	0,0136
Italy	0,0517	0,0463	0,0360	0,0423	0,0465	0,0226
Japan	0,0604	0,0608	0,0222	0,0457	0,0418	0,0434
Korea	0,0562	0,0604	0,0533	0,0596	0,0596	0,0307
Latvia	0,0051	0,0177	0,0228	0,0107	0,0152	0,0096
Lithuania	0,0191	0,0212	0,0165	0,0141	0,0106	0,0293
Luxembourg	0,0239	0,0364	0,0364	0,0350	0,0523	0,0179
Mexico	0,1164	0,1218	0,1218	0,1215	0,1263	0,0055
Netherlands	0,0305	0,0310	0,0103	0,0194	0,0194	0,0209
New Zeeland	0,0301	0,0246	0,0478	0,0404	0,0361	0,0326
Norway	0,0307	0,0389	0,0547	0,0544	0,0586	0,0470
Poland	0,0208	0,0286	0,0381	0,0356	0,0269	0,0186
Portugal	0,0244	0,0310	0,0066	0,0194	0,0000	0,0436
Slovak Republic	0,0520	0,0446	0,0293	0,0380	0,0332	0,0206
Slovenia	0,0469	0,0438	0,0346	0,0182	0,0025	0,0251
Spain	0,0240	0,0278	0,0234	0,0204	0,0285	0,0127
Sweden	0,0419	0,0464	0,0122	0,0349	0,0310	0,0385
Switzerland	0,0333	0,0343	0,0015	0,0182	0,0143	0,0367
Türkiye	0,0086	0,0165	0,0165	0,0095	0,0095	0,0000
United Kingdom	0,0448	0,0482	0,0521	0,0496	0,0472	0,0220
United States	0,0508	0,0546	0,0328	0,0433	0,0551	0,0346

Eqs. (19–20) were used to determine the summation of absolute deviations and the final weights of criteria, respectively. The results obtained from the MEREC method are presented in Table 12.

Table 12: Results of the MEREC Method

	C_1	C_2	C_3	C_4	C_5	C_6
E_j	0,8837	0,7587	0,8853	0,8224	0,8412	1,1224
W_j	0,1663	0,1428	0,1666	0,1548	0,1583	0,2112
Rank	3	6	2	5	4	1

The results of the MEREC method showed that C_6 (tracking and tracing) and C_2 (infrastructure) were the most and least important criteria, respectively. Additionally, the general ranking of criteria was determined as follows: $C_6 > C_3 > C_1 > C_5 > C_4 > C_2$.

4.5. The Results Obtained from the AWM Method

According to Equation (21), the results were combined with the AWM, and the final weights and rankings are shown in Table 13.

Table 13: Overall Results

Criteria/ Weight	C_1	C_2	C_3	C_4	C_5	C_6
W_{jSD}	0,1687	0,1670	0,1371	0,1639	0,1860	0,1773
	3	4	6	5	1	2
$W_{jCRITIC}$	0,1688	0,1410	0,2177	0,1158	0,1651	0,1916
	3	5	1	6	4	2
$W_{jLOPCOW}$	0,1770	0,1683	0,1792	0,1787	0,1494	0,1474
	3	4	1	2	5	6
W_{jMEREC}	0,1663	0,1428	0,1666	0,1548	0,1583	0,2112
	3	6	2	5	4	1
W_{jAWM}	0,1702	0,1548	0,1751	0,1533	0,1647	0,1819
	3	5	2	6	4	1

According to results obtained from the AWM, C_6 (tracking and tracing) was the most important criterion, followed by C_3 (international shipments) and C_1 (customs). On the other hand, C_4 (logistics competence and quality) was the least important criterion, followed by C_2 (infrastructure) and C_5 (timeliness). A comparison of the results obtained from each method is presented in Figure 1.

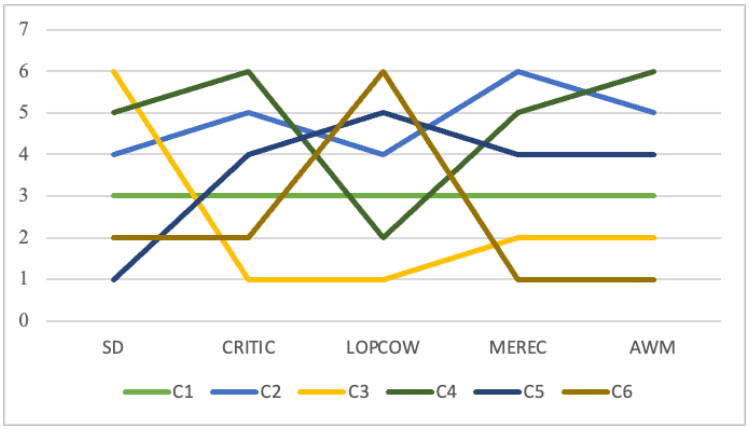

Figure 1: Comparison Results Based on Different Methods

As shown above, the different ranking results were obtained using each method. It can be concluded that each method has different approaches and formulations. Therefore, it can be stated that the AWM provides more consistent and reliable results. Correspondingly, the results obtained from the AWM were used to rank countries. In the following section, the results of the CRADIS method are presented.

4.3. The Results Obtained from the CRADIS Method

The decision matrix was normalized using Equation (22) and is presented in Table 14.

Table 14: Normalized-Decision Matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,9024	0,9318	0,7561	0,9070	0,9535	0,8372
Austria	0,9024	0,8864	0,9268	0,9302	0,9767	1,0000
Belgium	0,9512	0,9318	0,9268	0,9767	0,9302	0,9767
Canada	0,9756	0,9773	0,8780	0,9767	0,9535	0,9535
Chile	0,7317	0,6364	0,6585	0,7209	0,6977	0,7442
Colombia	0,6098	0,6591	0,7317	0,7209	0,7209	0,7442
Costa Rica	0,6829	0,6136	0,6829	0,6744	0,6744	0,7442
Czech Republic	0,7317	0,6818	0,8293	0,8372	0,7442	0,8605
Denmark	1,0000	0,9318	0,8780	0,9535	1,0000	0,9535
Estonia	0,7805	0,7955	0,8293	0,8605	0,8837	0,9535
Finland	0,9756	0,9545	1,0000	0,9767	0,9767	1,0000
France	0,9024	0,8636	0,9024	0,8837	0,9302	0,9535
Germany	0,9512	0,9773	0,9024	0,9767	0,9767	0,9535
Greece	0,7805	0,8409	0,9268	0,8837	0,9070	0,9070
Hungary	0,6585	0,7045	0,8293	0,7209	0,7907	0,8372
Iceland	0,9024	0,8182	0,8049	0,8140	0,8605	0,8372

Ireland	0,8293	0,7955	0,8780	0,8372	0,8605	0,8605
Israel	0,8293	0,8409	0,8537	0,8837	0,8605	0,8837
Italy	0,8293	0,8636	0,8293	0,8837	0,9070	0,9070
Japan	0,9512	0,9545	0,8049	0,9535	0,9302	0,9302
Korea	0,9512	0,9318	0,8293	0,8837	0,8837	0,8837
Latvia	0,8049	0,7500	0,7805	0,8605	0,8372	0,9302
Lithuania	0,7805	0,7955	0,8293	0,8372	0,7209	0,8372
Luxembourg	0,8780	0,8182	0,8780	0,9070	0,8140	0,8140
Mexico	0,6098	0,6364	0,6829	0,6977	0,7209	0,8140
Netherlands	0,9512	0,9545	0,9024	0,9767	0,9767	0,9302
New Zealand	0,8293	0,8636	0,7805	0,8605	0,8837	0,8837
Norway	0,9268	0,8864	0,7317	0,8837	0,8605	0,9302
Poland	0,8293	0,7955	0,8049	0,8372	0,8837	0,9070
Portugal	0,7805	0,8182	0,7561	0,8372	0,7442	0,8372
Slovak Republic	0,7805	0,7500	0,7317	0,7907	0,7674	0,8140
Slovenia	0,8293	0,8182	0,8293	0,7674	0,6977	0,7674
Spain	0,8780	0,8636	0,9024	0,9070	0,9535	0,9767
Sweden	0,9756	0,9545	0,8293	0,9767	0,9535	0,9767
Switzerland	1,0000	1,0000	0,8780	1,0000	0,9767	0,9767
Türkiye	0,7317	0,7727	0,8293	0,8140	0,8140	0,8372
United Kingdom	0,8537	0,8409	0,8537	0,8605	0,9302	0,8605
United States	0,9024	0,8864	0,8293	0,9070	0,9767	0,8837

According to Equation (24), the weighted normalized decision matrix was formed, as shown in Table 15.

Table 15: Weighted Normalized Decision Matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,1536	0,1442	0,1324	0,1390	0,1570	0,1523
Austria	0,1536	0,1372	0,1623	0,1426	0,1609	0,1819
Belgium	0,1619	0,1442	0,1623	0,1497	0,1532	0,1777
Canada	0,1661	0,1513	0,1538	0,1497	0,1570	0,1734
Chile	0,1245	0,0985	0,1153	0,1105	0,1149	0,1354
Colombia	0,1038	0,1020	0,1282	0,1105	0,1187	0,1354
Costa Rica	0,1162	0,0950	0,1196	0,1034	0,1111	0,1354
Czech Republic	0,1245	0,1055	0,1452	0,1283	0,1226	0,1565
Denmark	0,1702	0,1442	0,1538	0,1462	0,1647	0,1734
Estonia	0,1328	0,1231	0,1452	0,1319	0,1456	0,1734
Finland	0,1661	0,1477	0,1751	0,1497	0,1609	0,1819
France	0,1536	0,1337	0,1581	0,1355	0,1532	0,1734
Germany	0,1619	0,1513	0,1581	0,1497	0,1609	0,1734
Greece	0,1328	0,1301	0,1623	0,1355	0,1494	0,1650
Hungary	0,1121	0,1090	0,1452	0,1105	0,1302	0,1523
Iceland	0,1536	0,1266	0,1410	0,1248	0,1417	0,1523
Ireland	0,1411	0,1231	0,1538	0,1283	0,1417	0,1565

Israel	0,1411	0,1301	0,1495	0,1355	0,1417	0,1607
Italy	0,1411	0,1337	0,1452	0,1355	0,1494	0,1650
Japan	0,1619	0,1477	0,1410	0,1462	0,1532	0,1692
Korea	0,1619	0,1442	0,1452	0,1355	0,1456	0,1607
Latvia	0,1370	0,1161	0,1367	0,1319	0,1379	0,1692
Lithuania	0,1328	0,1231	0,1452	0,1283	0,1187	0,1523
Luxembourg	0,1495	0,1266	0,1538	0,1390	0,1341	0,1480
Mexico	0,1038	0,0985	0,1196	0,1069	0,1187	0,1480
Netherlands	0,1619	0,1477	0,1581	0,1497	0,1609	0,1692
New Zeeland	0,1411	0,1337	0,1367	0,1319	0,1456	0,1607
Norway	0,1578	0,1372	0,1282	0,1355	0,1417	0,1692
Poland	0,1411	0,1231	0,1410	0,1283	0,1456	0,1650
Portugal	0,1328	0,1266	0,1324	0,1283	0,1226	0,1523
Slovak Republic	0,1328	0,1161	0,1282	0,1212	0,1264	0,1480
Slovenia	0,1411	0,1266	0,1452	0,1176	0,1149	0,1396
Spain	0,1495	0,1337	0,1581	0,1390	0,1570	0,1777
Sweden	0,1661	0,1477	0,1452	0,1497	0,1570	0,1777
Switzerland	0,1702	0,1548	0,1538	0,1533	0,1609	0,1777
Türkiye	0,1245	0,1196	0,1452	0,1248	0,1341	0,1523
United Kingdom	0,1453	0,1301	0,1495	0,1319	0,1532	0,1565
United States	0,1536	0,1372	0,1452	0,1390	0,1609	0,1607

The ideal and anti-ideal solution was determined using Eqs. (25-26), and the results are shown in Table 16 and 17, respectively.

Table 16: Ideal Solution

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	0,0283	0,0377	0,0495	0,0429	0,0248	0,0296
Austria	0,0283	0,0447	0,0196	0,0393	0,0210	0,0000
Belgium	0,0200	0,0377	0,0196	0,0322	0,0287	0,0042
Canada	0,0158	0,0306	0,0281	0,0322	0,0248	0,0085
Chile	0,0573	0,0834	0,0666	0,0714	0,0670	0,0465
Colombia	0,0781	0,0799	0,0537	0,0714	0,0631	0,0465
Costa Rica	0,0656	0,0869	0,0623	0,0785	0,0708	0,0465
Czech Republic	0,0573	0,0764	0,0366	0,0536	0,0593	0,0254
Denmark	0,0117	0,0377	0,0281	0,0357	0,0172	0,0085
Estonia	0,0490	0,0588	0,0366	0,0500	0,0363	0,0085
Finland	0,0158	0,0342	0,0067	0,0322	0,0210	0,0000
France	0,0283	0,0482	0,0238	0,0464	0,0287	0,0085
Germany	0,0200	0,0306	0,0238	0,0322	0,0210	0,0085
Greece	0,0490	0,0517	0,0196	0,0464	0,0325	0,0169
Hungary	0,0698	0,0728	0,0366	0,0714	0,0517	0,0296
Iceland	0,0283	0,0553	0,0409	0,0571	0,0402	0,0296
Ireland	0,0407	0,0588	0,0281	0,0536	0,0402	0,0254

Israel	0,0407	0,0517	0,0324	0,0464	0,0402	0,0211
Italy	0,0407	0,0482	0,0366	0,0464	0,0325	0,0169
Japan	0,0200	0,0342	0,0409	0,0357	0,0287	0,0127
Korea	0,0200	0,0377	0,0366	0,0464	0,0363	0,0211
Latvia	0,0449	0,0658	0,0452	0,0500	0,0440	0,0127
Lithuania	0,0490	0,0588	0,0366	0,0536	0,0631	0,0296
Luxembourg	0,0324	0,0553	0,0281	0,0429	0,0478	0,0338
Mexico	0,0781	0,0834	0,0623	0,0749	0,0631	0,0338
Netherlands	0,0200	0,0342	0,0238	0,0322	0,0210	0,0127
New Zealand	0,0407	0,0482	0,0452	0,0500	0,0363	0,0211
Norway	0,0241	0,0447	0,0537	0,0464	0,0402	0,0127
Poland	0,0407	0,0588	0,0409	0,0536	0,0363	0,0169
Portugal	0,0490	0,0553	0,0495	0,0536	0,0593	0,0296
Slovak Republic	0,0490	0,0658	0,0537	0,0607	0,0555	0,0338
Slovenia	0,0407	0,0553	0,0366	0,0642	0,0670	0,0423
Spain	0,0324	0,0482	0,0238	0,0429	0,0248	0,0042
Sweden	0,0158	0,0342	0,0366	0,0322	0,0248	0,0042
Switzerland	0,0117	0,0271	0,0281	0,0286	0,0210	0,0042
Türkiye	0,0573	0,0623	0,0366	0,0571	0,0478	0,0296
United Kingdom	0,0366	0,0517	0,0324	0,0500	0,0287	0,0254
United States	0,0283	0,0447	0,0366	0,0429	0,0210	0,0211
Min	0,0117	0,0271	0,0067	0,0286	0,0172	0,0000

Table 17: Anti-ideal Solution

Economy	C_1	C_2	C_3	C_4	C_5	C_6
Australia	-0,0586	-0,0492	-0,0375	-0,0441	-0,0621	-0,0573
Austria	-0,0586	-0,0422	-0,0674	-0,0476	-0,0659	-0,0869
Belgium	-0,0669	-0,0492	-0,0674	-0,0548	-0,0582	-0,0827
Canada	-0,0711	-0,0563	-0,0588	-0,0548	-0,0621	-0,0785
Chile	-0,0296	-0,0035	-0,0204	-0,0155	-0,0199	-0,0404
Colombia	-0,0088	-0,0070	-0,0332	-0,0155	-0,0238	-0,0404
Costa Rica	-0,0213	0,0000	-0,0246	-0,0084	-0,0161	-0,0404
Czech Republic	-0,0296	-0,0106	-0,0503	-0,0334	-0,0276	-0,0615
Denmark	-0,0752	-0,0492	-0,0588	-0,0512	-0,0697	-0,0785
Estonia	-0,0379	-0,0281	-0,0503	-0,0369	-0,0506	-0,0785
Finland	-0,0711	-0,0528	-0,0802	-0,0548	-0,0659	-0,0869
France	-0,0586	-0,0387	-0,0631	-0,0405	-0,0582	-0,0785
Germany	-0,0669	-0,0563	-0,0631	-0,0548	-0,0659	-0,0785
Greece	-0,0379	-0,0352	-0,0674	-0,0405	-0,0544	-0,0700
Hungary	-0,0171	-0,0141	-0,0503	-0,0155	-0,0353	-0,0573
Iceland	-0,0586	-0,0317	-0,0460	-0,0298	-0,0468	-0,0573
Ireland	-0,0462	-0,0281	-0,0588	-0,0334	-0,0468	-0,0615
Israel	-0,0462	-0,0352	-0,0545	-0,0405	-0,0468	-0,0658
Italy	-0,0462	-0,0387	-0,0503	-0,0405	-0,0544	-0,0700

Japan	-0,0669	-0,0528	-0,0460	-0,0512	-0,0582	-0,0742
Korea	-0,0669	-0,0492	-0,0503	-0,0405	-0,0506	-0,0658
Latvia	-0,0420	-0,0211	-0,0417	-0,0369	-0,0429	-0,0742
Lithuania	-0,0379	-0,0281	-0,0503	-0,0334	-0,0238	-0,0573
Luxembourg	-0,0545	-0,0317	-0,0588	-0,0441	-0,0391	-0,0531
Mexico	-0,0088	-0,0035	-0,0246	-0,0120	-0,0238	-0,0531
Netherlands	-0,0669	-0,0528	-0,0631	-0,0548	-0,0659	-0,0742
New Zeeland	-0,0462	-0,0387	-0,0417	-0,0369	-0,0506	-0,0658
Norway	-0,0628	-0,0422	-0,0332	-0,0405	-0,0468	-0,0742
Poland	-0,0462	-0,0281	-0,0460	-0,0334	-0,0506	-0,0700
Portugal	-0,0379	-0,0317	-0,0375	-0,0334	-0,0276	-0,0573
Slovak Republic	-0,0379	-0,0211	-0,0332	-0,0262	-0,0314	-0,0531
Slovenia	-0,0462	-0,0317	-0,0503	-0,0227	-0,0199	-0,0446
Spain	-0,0545	-0,0387	-0,0631	-0,0441	-0,0621	-0,0827
Sweden	-0,0711	-0,0528	-0,0503	-0,0548	-0,0621	-0,0827
Switzerland	-0,0752	-0,0598	-0,0588	-0,0583	-0,0659	-0,0827
Türkiye	-0,0296	-0,0246	-0,0503	-0,0298	-0,0391	-0,0573
United Kingdom	-0,0503	-0,0352	-0,0545	-0,0369	-0,0582	-0,0615
United States	-0,0586	-0,0422	-0,0503	-0,0441	-0,0659	-0,0658
Max	-0,0088	0,0000	-0,0204	-0,0084	-0,0161	-0,0404

Based on Eqs. (27-28), the deviations from ideal and anti-ideal solutions were calculated. The grades of deviation of individual alternatives from ideal and anti-ideal solutions were determined using the following equations. (29-30). The utility function for each alternative was computed by Eqs. (31-32). The final ranking of alternatives was determined using Equation (33). The results obtained from the CRADIS method are shown in Table 18.

Table 18: Results of the CRADIS Method

Economy	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	Rank
Australia	0,2127	0,4293	-0,3088	3,2818	1,8556	15
Austria	0,1529	0,5974	-0,3686	3,9182	2,2578	9
Belgium	0,1423	0,6419	-0,3792	4,0306	2,3362	6
Canada	0,1400	0,6521	-0,3815	4,0544	2,3533	5
Chile	0,3922	0,2329	-0,1293	1,3745	0,8037	35
Colombia	0,3928	0,2325	-0,1287	1,3682	0,8003	36
Costa Rica	0,4107	0,2224	-0,1108	1,1778	0,7001	38
Czech Republic	0,3086	0,2959	-0,2129	2,2628	1,2793	32
Denmark	0,1388	0,6578	-0,3827	4,0673	2,3626	4
Estonia	0,2392	0,3817	-0,2822	3,0000	1,6908	21
Finland	0,1099	0,8309	-0,4116	4,3747	2,6028	1
France	0,1839	0,4966	-0,3376	3,5883	2,0424	12
Germany	0,1361	0,6711	-0,3854	4,0964	2,3838	3
Greece	0,2162	0,4224	-0,3053	3,2450	1,8337	16
Hungary	0,3319	0,2751	-0,1896	2,0148	1,1450	34

Iceland	0,2514	0,3633	-0,2701	2,8713	1,6173	26
Ireland	0,2467	0,3702	-0,2748	2,9206	1,6454	24
Israel	0,2326	0,3926	-0,2889	3,0707	1,7317	20
Italy	0,2215	0,4124	-0,3000	3,1890	1,8007	17
Japan	0,1721	0,5305	-0,3493	3,7132	2,1218	10
Korea	0,1982	0,4607	-0,3233	3,4362	1,9485	14
Latvia	0,2626	0,3478	-0,2589	2,7521	1,5500	27
Lithuania	0,2908	0,3141	-0,2307	2,4523	1,3832	28
Luxembourg	0,2403	0,3800	-0,2812	2,9885	1,6843	22
Mexico	0,3957	0,2308	-0,1258	1,3370	0,7839	37
Netherlands	0,1438	0,6349	-0,3777	4,0141	2,3245	7
New Zealand	0,2416	0,3780	-0,2799	2,9747	1,6763	23
Norway	0,2218	0,4116	-0,2996	3,1849	1,7982	18
Poland	0,2472	0,3694	-0,2743	2,9150	1,6422	25
Portugal	0,2962	0,3083	-0,2253	2,3942	1,3512	30
Slovak Republic	0,3186	0,2866	-0,2029	2,1566	1,2216	33
Slovenia	0,3062	0,2983	-0,2153	2,2887	1,2935	31
Spain	0,1764	0,5176	-0,3451	3,6677	2,0927	11
Sweden	0,1479	0,6176	-0,3736	3,9712	2,2944	8
Switzerland	0,1207	0,7563	-0,4008	4,2595	2,5079	2
Türkiye	0,2908	0,3140	-0,2307	2,4516	1,3828	29
United Kingdom	0,2247	0,4063	-0,2967	3,1541	1,7802	19
United States	0,1947	0,4691	-0,3268	3,4739	1,9715	13
$S0_+$	0,0913	$S0_-$	-0,0941			

Based on the results obtained from the CRADIS method, Finland ranks first in logistics performance among OECD countries, followed by Switzerland in second place. Germany, in fourth place behind Denmark, and Canada, in fifth place, occupy the third place in the ranking. Additionally, the worst-ranked logistics performance among OECD countries is found in Costa Rica, followed by Mexico, Colombia, Chile, and Hungary. The results obtained from the proposed model may be affected by certain conditions, such as changes in the criteria weights and modifications to the methods and alternatives. Therefore, in the following section, sensitivity and comparative analysis were performed to confirm these results.

4.4. Sensitivity and Comparative Analysis

As stated by Pamučar et al. (2017), the purpose of sensitivity analysis is to determine whether changes in the weights of the criteria result in changes in the ranking of alternatives. However, merely changing the weight of the criteria is insufficient to ensure the reliability of the results. Therefore, it is essential to conduct a consistent analysis of these results in light of the methodological changes (Mešić et al., 2022, p. 29). In this study, sensitivity and comparative analysis were conducted to monitor the robustness of the results obtained from the proposed model. The reliability of the proposed model was conducted through two steps. Firstly, the alternatives were reordered based on the values obtained from the different weighting methods to determine the impact of criterion weights on the general ranking. Secondly, the results obtained from the proposed model were compared with the results obtained by applying other MCDM methods. For this

purpose, six methods were used: MABAC, EDAS, MARCOS, SAW, ARAS, and TOPSIS. Table 19 illustrates the results obtained by applying different weight criteria and MCDM methods.

Table 19: Results Based on Different Criteria Weights

Economy	SD		CRITIC		LOPCOW		MEREC	
	Q	Rank	*Q*	Rank	*Q*	Rank	*Q*	Rank
Australia	1,6655	15	1,3779	16	2,6735	15	1,5861	15
Austria	1,9576	9	1,6182	8	3,2399	9	1,8779	9
Belgium	2,0224	7	1,6476	5	3,3981	6	1,9239	6
Canada	2,0550	5	1,6449	6	3,4356	4	1,9297	5
Chile	0,7885	35	0,8357	36	0,9346	35	0,8579	35
Colombia	0,7777	36	0,8428	35	0,9237	36	0,8533	36
Costa Rica	0,6972	38	0,7904	38	0,7505	38	0,7863	38
Czech Republic	1,1471	32	1,0995	32	1,7116	32	1,1998	31
Denmark	2,0637	4	1,6550	4	3,4294	5	1,9362	4
Estonia	1,4969	22	1,3163	21	2,3479	23	1,4933	21
Finland	2,2273	1	1,7845	1	3,7825	1	2,0832	1
France	1,7779	12	1,5084	12	2,9193	12	1,7296	12
Germany	2,0778	3	1,6638	3	3,4764	3	1,9477	3
Greece	1,6015	17	1,4006	15	2,6025	16	1,5815	16
Hungary	1,0413	34	1,0396	34	1,4634	34	1,0998	34
Iceland	1,4402	26	1,2737	26	2,2714	26	1,4246	26
Ireland	1,4492	25	1,2982	23	2,3094	24	1,4472	25
Israel	1,5280	20	1,3343	20	2,4559	20	1,5099	20
Italy	1,5946	18	1,3677	17	2,5527	18	1,5599	18
Japan	1,8743	10	1,5205	11	3,0809	10	1,7790	10
Korea	1,7165	14	1,4419	14	2,8147	14	1,6550	14
Latvia	1,3850	27	1,2348	27	2,1308	27	1,3954	27
Lithuania	1,2343	29	1,1495	29	1,9093	28	1,2648	28
Luxembourg	1,4813	23	1,3078	22	2,4177	21	1,4686	23
Mexico	0,7692	37	0,8335	37	0,8640	37	0,8524	37
Netherlands	2,0277	6	1,6351	7	3,3930	7	1,9080	7
New Zeeland	1,4996	21	1,2962	24	2,3585	22	1,4716	22
Norway	1,6066	16	1,3517	19	2,5537	17	1,5633	17
Poland	1,4616	24	1,2878	25	2,2824	25	1,4529	24
Portugal	1,2254	30	1,1216	30	1,8541	30	1,2430	30
Slovak Republic	1,1226	33	1,0566	33	1,6262	33	1,1516	33
Slovenia	1,1594	31	1,1061	31	1,7787	31	1,1911	32
Spain	1,8227	11	1,5327	10	2,9891	11	1,7670	11
Sweden	2,0153	8	1,6102	9	3,3321	8	1,8983	8
Switzerland	2,1893	2	1,7145	2	3,6651	2	2,0265	2
Türkiye	1,2412	28	1,1533	28	1,8835	29	1,2639	29
United Kingdom	1,5740	19	1,3625	18	2,5263	19	1,5386	19
United States	1,7448	13	1,4536	13	2,8327	13	1,6718	13

From the table above, it can be seen that the ranking results obtained by the AWM are nearly identical to those obtained from the SD, CRITIC, LOPCOW, and MEREC methods individually. Additionally, a correlation analysis was conducted for the values obtained from the CRADIS method using individual weights and the ranking value. Table 20 presents the results of the correlation analysis.

Table 20: Correlation Coefficient Results

Value of Methods				
	SD	**CRITIC**	**LOPCOW**	**MEREC**
SD	**1,0000**	0,9980	0,9991	0,9992
CRITIC		**1,0000**	0,9987	0,9994
LOPCOW			**1,0000**	0,9992
MEREC				**1,0000**
Value of Rank				
	SD	**CRITIC**	**LOPCOW**	**MEREC**
SD	**1,0000**	0,9952	0,9982	0,9989
CRITIC		**1,0000**	0,9965	0,9967
LOPCOW			**1,0000**	0,9985
MEREC				**1,0000**

The table above illustrates the greatest correlation between the CRITIC and MEREC methods ($r = 0.9994$) for ranking the alternatives. These results are consistent with those of Das and Chakraborty (2023), who found high degrees of congruence in the rankings based on the CRITIC and MEREC methods. Although the alternatives have almost the same ranking according to the weight obtained by the SD, CRITIC, LOPCOW, and MEREC methods, the situation is slightly different in the ranking of alternatives regarding the value of rank. The ranking order of the weights obtained by the MEREC method deviates from these due to the different ranks of the alternatives ($r = 0.9967$). It is also noticeable that the results obtained from the CRITIC method deviated relatively from the other results. However, in addition to the different ranking order, Finland and Costa Rica have the best and worst logistics performance, respectively. Furthermore, to compare the results obtained from other MCDM methods with those of the proposed model, a comparative analysis was conducted, and its results are presented in Table 21.

Table 21: Rank of Alternatives Based on Different Methods

Economy	CRADIS	MABAC	EDAS	MARCOS	SAW	ARAS	TOPSIS
Australia	15	16	15	15	15	15	19
Austria	9	9	9	9	9	9	8
Belgium	6	5	6	6	6	6	3
Canada	5	6	5	5	5	5	6
Chile	35	37	35	35	35	35	35
Colombia	36	36	36	36	36	36	36
Costa Rica	38	38	38	38	38	38	38
Czech Republic	32	31	32	32	32	32	32
Denmark	4	4	4	4	4	4	7
Estonia	21	21	22	21	21	22	24

Finland	1	1	1	1	1	1	1
France	12	12	12	12	12	12	11
Germany	3	3	3	3	3	3	2
Greece	16	15	16	16	16	16	15
Hungary	34	34	34	34	34	34	34
Iceland	26	26	26	26	26	26	25
Ireland	24	25	24	24	24	24	22
Israel	20	20	20	20	20	20	18
Italy	17	17	17	17	17	17	17
Japan	10	11	10	10	10	10	12
Korea	14	14	14	14	14	14	14
Latvia	27	27	27	27	27	27	27
Lithuania	28	29	28	28	28	28	28
Luxembourg	22	24	21	22	22	21	20
Mexico	37	35	37	37	37	37	37
Netherlands	7	7	7	7	7	7	5
New Zealand	23	22	23	23	23	23	23
Norway	18	18	18	18	18	18	21
Poland	25	23	25	25	25	25	26
Portugal	30	30	30	30	30	30	30
Slovak Republic	33	33	33	33	33	33	33
Slovenia	31	32	31	31	31	31	31
Spain	11	10	11	11	11	11	10
Sweden	8	8	8	8	8	8	9
Switzerland	2	2	2	2	2	2	4
Türkiye	29	28	29	29	29	29	29
United Kingdom	19	19	19	19	19	19	16
United States	13	13	13	13	13	13	13

The comparative analysis results showed that the ranking order obtained from the CRADIS method is nearly identical to that obtained from the EDAS, MARCOS, SAW, and ARAS methods. However, the rankings differ between the MABAC and TOPSIS methods. These results were confirmed by the correlation analysis, which showed that the MABAC and TOPSIS methods had the most significant deviation from the other results. Table 22 demonstrates the correlation coefficient results of the methods used in the comparative analysis.

Table 22: Correlation Coefficient Results

	CRADIS	MABAC	EDAS	MARCOS	SAW	ARAS	TOPSIS
CRADIS	**1,0000**	0,9969	0,9998	1,0000	1,0000	0,9998	0,9897
MABAC	-	**1,0000**	0,9963	0,9969	0,9969	0,9963	0,9875
EDAS	-	-	**1,0000**	0,9998	0,9998	1,0000	0,9906
MARCOS	-	-	-	**1,0000**	1,0000	0,9998	0,9897
SAW	-	-	-	-	**1,0000**	0,9998	0,9897
ARAS	-	-	-	-	-	**1,0000**	0,9906
TOPSIS	-	-	-	-	-	-	**1,0000**

The table above illustrates the greatest correlation between CRADIS and EDAS, MARCOS, SAW, and ARAS methods for ranking the alternatives. These results are consistent with those of Yuan et al. (2023) and Keleş (2023), who found high degrees of congruence in the rankings based on the CRADIS and EDAS, MARCOS, SAW, and ARAS methods. The overall ranking of countries, as determined by the comparative analysis, is presented in Figure 2.

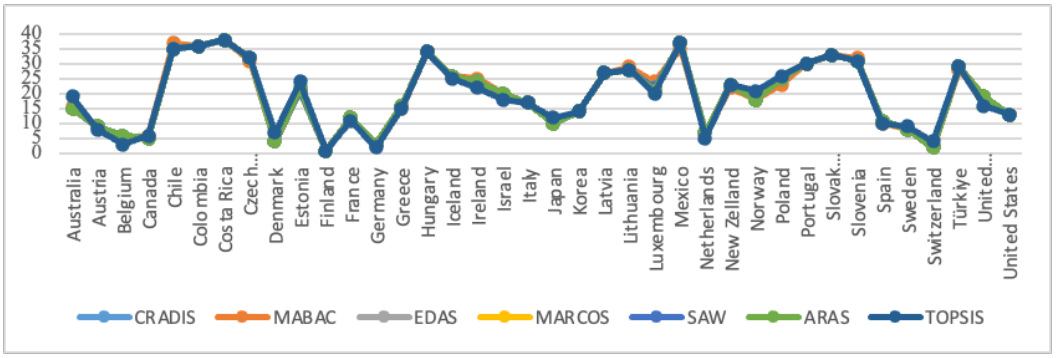

Figure 2: Comparative Analysis Results

The comparative analysis showed that Finland and Costa Rica have the best and worst logistics performance, respectively. It can be concluded that the countries with the highest and lowest logistics performance are constant for all methods. In addition to evaluating the results based on comparative analysis, the results obtained from the proposed model were compared with those from the LPI 2023 report. Figure 3 illustrates the comparison of logistics performance among OECD countries based on the proposed model and the LPI 2023 report.

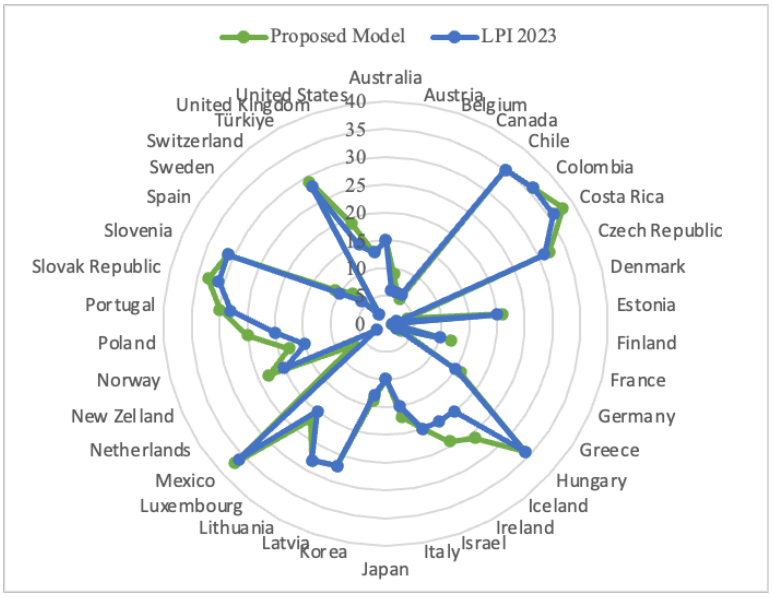

Figure 3: Comparison Results of the Proposed Model and LPI 2023 Report

As shown in Figure 3, the ranking order obtained from the proposed model is nearly identical to that in the LPI 2023 report. Although slight differences were observed between the proposed model and the LPI 2023 report, the overall ranking remained unchanged from that in the original report. Thus, it can be concluded that the reliability and robustness of the proposed model were confirmed.

5. Discussion and Conclusion

The logistics sector plays a vital role in driving the global economy's growth. It is essential to the success of economies and businesses, as it involves the management and movement of resources and goods from one place to another. Therefore, the LPI was developed by the World Bank to measure the efficiency of logistics operations worldwide. It was the first tool that enabled countries to assess their logistics performance relative to other countries using various indicators. The LPI and its elements are among the best indicators, providing a snapshot of a country's logistics position relative to its peers or competitors. Analyzing the logistics performance and comprehending its drivers have become more important than ever due to the significant changes in the global market since the Covid-19 pandemic and the Russia-Ukraine war. During the COVID-19 pandemic, many countries were affected negatively due to the unavailability of truck drivers and the shutdown of ports and warehouses. Additionally, the Russia-Ukraine war led to an increase in food and energy prices due to the disruption of container shipping from Russia, Ukraine, and Belarus to the rest of the world (Arvis et al., 2023). In light of this information, it can be concluded that assessing the recent logistics performance of countries is crucial.

In this study, the LPI of OECD countries was examined using the hybrid MCDM methods. For this investigation, a new model was proposed, which involves SD, CRITIC, LOPCOW, MEREC, and CRADIS methods, in order to evaluate the LPI of OECD countries. A total of thirty-eight countries were evaluated based on six criteria. The 2023 LPI data was used to analyze and compare the logistics performance of countries. Several objective methods were employed to determine the weight of the criteria, and the CRADIS method was used to rank countries based on their logistics performance. The results obtained from several weighting methods showed that a different ranking was obtained from each method. The overall results of the weight of criteria showed that tracking and tracing, international shipments, and customs were the most important criteria, while logistics competence, quality, infrastructure, and timeliness were the least important criteria, respectively. Once the weight of the criteria was determined, the logistics performance of countries was ranked by the CRADIS method. The results showed that Finland, Switzerland, Germany, Denmark, Canada, Belgium, Netherlands, Sweden, Austria, and Japan were in the top ten. At the same time, Costa Rica, Mexico, Colombia, Chile, Hungary, Slovak Republic, Czech Republic, Slovenia, Portugal, and Türkiye were the last ten ranked. The results obtained from the proposed model were confirmed by sensitivity analysis, comparative analysis, and spearmen correlation analysis. Additionally, the proposed model was compared with the LPI 2023 report. Overall, it can be observed that there is a significant correlation between the results.

The findings of the current study are consistent with those of Çakır (2017), Orhan (2019), Ulutaş and Karaköy (2019a), who found that tracking and tracing, and customs were the most important

criteria. However, the findings of the current study do not support the findings of Rezaei et al. (2018), Ulutaş and Karaköy (2019b), Isik et al. (2020); Mešić et al. (2022), Miškić et al. (2023), who found that infrastructure and timeliness were the most important criteria. A possible explanation for these results might be related to the different mathematical formulation of the methods. This assumption is also supported by the current study, which obtained different results from various methods (SD, CRITIC, LOPCOW, and MEREC). As mentioned above, different ranking results were obtained from each weighting method. Additionally, it has been observed that the ranking of countries in terms of logistics performance differs from previous studies. Much of the available literature (Çakır, 2017; Ulutaş & Karaköy, 2019b; Miškić et al., 2023; Gürler et al., 2024) on LPI showed that Germany has the best logistics performance. In contrast to many studies, Finland was determined as the country with the best logistics performance, followed by Switzerland and Germany. It also has been observed that 8 of the top 10 countries with the highest logistics performance are from Europe. Apart from this, almost half of the last 10 countries with the lowest logistics performance are from Latin America. Based on this, it can be concluded that advanced economies have demonstrated remarkable logistics performance while developing economies have shown limited logistics performance. Notably, Finland has seen a significant improvement in its logistics performance over the last decade. Finland was ranked 24th, 15th, and 10th in the 2014, 2016, and 2018 LPI reports, respectively. Therefore, it can be stated that Finland has shown significant growth in logistics performance in the last decade.

Overall, the present study was designed to measure the LPI of OECD countries. It is believed that the findings obtained from this study will provide policymakers, investors, and businesses in OECD countries with insight into logistics performance. Furthermore, this study identified which countries should be given priority by managers of logistics companies operating in OECD countries or those considering investment in these countries, as well as the criteria that managers should focus on when entering relevant markets. Besides that, several managerial suggestions have been made to improve the logistics performance of countries. For instance, universities and educational institutions can train future logistics professionals by offering more comprehensive training programs in logistics management. (2) Academic institutions can follow recent developments in the logistics sector and focus on research that produces new technological and managerial solutions. (3) businesses might focus on emerging technologies such as blockchain, artificial intelligence, automation, and big data to optimize and monitor their logistics processes. (4) establishing closer collaborations and increasing information sharing among stakeholders within the supply chain might contribute to more effective management of logistics processes. Along with this, countries may focus on sustainable practices in energy saving, waste management, and transportation methods to reduce environmental impact.

Several limitations to this study need to be acknowledged. The scope of this research was limited to OECD countries. Further research could investigate different groups of countries, such as BRICS, the African Union, the Balkan States, ASEAN, and APEC, among others. One limitation of the study is that it was constrained by the data obtained from the 2023 LPI report. In future investigations, it might be possible to use different criteria to conduct more comprehensive results. Furthermore, it would be interesting to compare the results obtained from the different methods such as MAIRCA, CoCoSo, MACONT, etc. It would also be interesting to compare the results by year.

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