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COMPARATIVE ANALYSIS OF THE LOGISTICS PERFORMANCE INDEX OF CENTRAL AND EASTERN EUROPEAN COUNTRIES: A HYBRID LOPCOW-RAWEC MODEL

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Abstract

This study evaluates the logistics performance index of Central and Eastern European (CEE) countries using a hybrid Multi-Criteria Decision-Making (MCDM) model. It examines the logistics performance of CEE countries from 2010 to 2023. The countries included in this study are Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Estonia, Georgia, Hungary, Latvia, Lithuania, Moldova, Montenegro, North Macedonia, Poland, Romania, Serbia, Slovak Republic, Slovenia and Ukraine. The assessment of the logistics performance is conducted based on six criteria determined through a literature review: customs, infrastructure, international shipments, logistics competencies, quality, timeliness, and tracking and tracing. Data is obtained from the Logistics Performance Index (LPI) reports published by the World Bank. The criteria weights are determined using the Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) method, while the countries' logistics performance is ranked based on the Ranking of Alternatives with Weights of Criterion (RAWEC) method. Findings from the LOPCOW indicate that infrastructure, timeliness, and tracking and tracing are the most significant criteria from 2010 to 2023. The RAWEC analysis reveals that Poland, Czechia, Hungary, Slovenia, and Estonia performed the highest logistics performance between 2010 and 2023. Additionally, sensitivity and comparative analyses were conducted to ensure the robustness of the findings. The results of this research are expected to offer valuable insights into the logistics performance of CEE countries over the past several decades.

Implications for Central European audience: CEE should prioritize the implementation of advanced tracking and tracing systems to enhance supply chain visibility and operational efficiency. Establishing partnerships with technology providers to adopt AI and IoT solutions will enable real-time tracking and help quickly address delays.

Keywords: LPI; CEE; MCDM; LOPCOW; RAWEC
JEL Classification: C02, N73

1 Introduction

Logistics refers to the comprehensive range of operations and services involved in moving, storing, and managing goods. This encompasses freight forwarding, third-party logistics, customs brokerage, road transportation, operations at ports, airports, railways, and warehousing and refrigeration services. Logistics is crucial to economic activities both domestically and internationally. Efficient logistics can significantly reduce trade costs and is essential for promoting trade and regional integration. However, limited international connectivity, inadequate logistics infrastructure, substandard logistics services, and cumbersome trade procedures at and beyond borders have led to higher logistics costs (Arvis et al., 2024). In today's business environment, having a competitive and efficient logistics system is crucial for developing advantages in both regional and global markets. Strong logistics performance positively influences individual companies' business outcomes and the countries' overall logistics efficiency. Developed nations recognize the importance of investing in logistics and actively implement various strategies and policies to strengthen this sector. High-quality logistics performance plays a significant role in promoting the growth of international trade. Focusing on the logistics performance index (LPI) is vital to creating a more efficient logistics system (Ju et al., 2024). The World Bank launched the LPI in 2007 as a collection of country indicators to guide policymakers and practitioners (Arvis et al., 2007). Since its launch in 2007, the LPI has provided a comprehensive assessment from industry professionals regarding the ease of exporting goods to a target country. This evaluation considers factors such as infrastructure quality, the availability and effectiveness of logistics services, and challenges within the public sector. The LPI and its components should be regarded as a snapshot of a country's logistics capabilities relative to its peers or comparators. It can be a crucial instrument for examining a nation's logistics effectiveness in more depth. Moreover, it is a comprehensive measure that has assessed the entire supply chain for 139 to 160 countries in editions from 2007 to 2023. It is derived from a survey of nearly 1,000 logistics professionals worldwide and is valuable for comparing performance across nations. Additionally, it helps identify and prioritize key areas for reform within countries (Arvis et al., 2023). The measurement of LPI is considered an MCDM problem due to its integration of various complex processes and calculations. Accordingly, many studies have been conducted in recent decades to evaluate the logistics performance of various countries using MCDM methods.

Rezaei et al. (2018) analyze the relative importance of the LPI indicators using the Best-Worst Method (BWM). The results indicate that infrastructure is the most important criterion of the LPI. Ulutaş and Karaköy (2019) utilize integrated MCDM methods, combining the Step-Wise Weight Assessment Ratio Analysis (SWARA) and the Criteria Importance Through Intercriteria Correlation (CRITIC)-based Proximity Indexed Value (PIV) model to evaluate the LPI of European Union (EU) countries. The results show that infrastructure is the most important criterion, and Germany has a notable logistics performance compared to other EU countries. Isik et al. (2020) proposed a new model that combines Statistical Variance (SV) with the MABAC (Multi-Attributive Border Approximation Area Comparison) method to evaluate the LPI of 11 CEE countries. The findings highlight that timeliness is the most important criterion, with Czechia, Poland, and Hungary identified as the top performers in the LPI. A study conducted by Mešić et al. (2022) introduces a hybrid model that combines the CRITIC method with the Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) method to assess the LPI of Western Balkan countries.

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The findings indicate that timeliness is the most significant criterion, and Serbia has the highest logistics performance among these countries. Miškić et al. (2023) measure the LPI of the 27 EU member states using the MEthod based on the Removal Effects of Criteria (MEREC) and the MARCOS method. The results state that Germany has the highest logistics performance among EU states. A recent study by Özekenci (2024) proposed a hybrid model that combines the LOPCOW, the CRITIC, and the Entropy-based Evaluation based on distance from average solution (EDAS) method to analyze the LPI of the Organization of the Petroleum Exporting Countries (OPEC) countries. The findings indicate that infrastructure is the most critical criterion, with the United Arab Emirates achieving the highest LPI. Measuring logistics performance and understanding its determinants has become increasingly important due to their significant contributions to the global economy. This research combines a hybrid LOPCOW-based RAWEC decision model to analyze the logistics performance of 19 CEE countries between 2010 and 2023. The current study aims to address the following research questions:

- *RQ1. What are the critical factors influencing the logistics performance of CEE countries?*
- *RQ2. How do CEE countries perform in terms of logistics performance?*
- *RQ3. How has the logistics performance of CEE countries evolved from 2010 to 2023?*
- *RQ4. Does the logistics performance of CEE countries differ depending on the MCDM methods applied?*

Thus, this study evaluates the logistics performance of CEE countries using hybrid MCDM methods. The countries in CEE are crucial in the LPI because of their strategic geographical location and increasing integration into global supply chains. Situated as a bridge between Western Europe and Asia, these countries play a key role in facilitating economic growth, international trade, and connectivity (Wieser et al., 2024). Parallel to this, a new model is proposed incorporating a novel weighting approach (LOPCOW) and a new ranking-based method (RAWEC). The selection of this hybrid model can be summarized as follows: (i) The LOPCOW effectively manages negative values in raw data and reduces significant disparities in priority assignment among relevant criteria. (ii) It provides comprehensive solutions for criteria in hierarchical structures, whether classified as benefits or costs. (iii) It helps to align dimensional variations arising from data structure differences. (iv) It can be implemented using straightforward procedures that do not require complex calculations. (v) The RAWEC combines two stages into one process, reducing the number of steps needed. (vi) It emphasizes evaluating outcomes by examining deviations from ideal values rather than merely ranking options based on their decision matrix value. (vii) It includes only a few simple steps, making it user-friendly and demonstrating its significant potential in MCDM applications, as it does not require complicated calculations (Ecer & Pamucar, 2022; Puška et al., 2024; Sumrit & Keeratibhubordee, 2025).

The novelties of this study can be expressed as follows:

- A new hybrid approach is implemented as an integrated decision support model to evaluate the logistics performance of CEE countries.
- The LOPCOW-RAWEC framework is applied for the first time in the MCDM field to assess the logistics performance of CEE countries between 2010 and 2023.

- The developed hybrid method provides a decision support system to assist the private sector, policymakers, and other stakeholders in analyzing the logistics performance of CEE countries.
- A hybrid model is validated using sensitivity analysis and comparative analysis.

The rest of the paper is organized as follows: Section 2 outlines the data and research methodology, which includes the LOPCOW, the RAWEC, and Borda Count methods. Section 3 presents the findings obtained from the hybrid MCDM methods. Section 4 provides a summary of the results, along with managerial implications and future recommendations.

2 Data and Methodology

This paper assesses the logistics performance of CEE countries, which include Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Estonia, Georgia, Hungary, Latvia, Lithuania, Moldova, Montenegro, North Macedonia, Poland, Romania, Serbia, Slovak Republic, Slovenia, and Ukraine. This study offers a long-term analysis of logistics performance in these countries over the past few decades, specifically from 2010 to 2023. The methodology for calculating the LPI has undergone notable evolution, particularly from its initial edition in 2007 to subsequent updates. The 2007 LPI was initially based on seven components, but starting in 2009, the World Bank refined this approach by streamlining the components to six. These adjustments, introduced after 2007, enhanced the accuracy, comparability, and reliability of the LPI. The revised methodology offers a more comprehensive and standardized evaluation of logistics performance, making it a more effective tool for policymakers and businesses. Consequently, this study focuses on the period following 2007. Logistics performance analysis was conducted based on six criteria: customs, infrastructure, international shipments, logistics competence and quality, tracking and tracing, and timeliness. The criteria were determined through a literature review (Isik et al., 2020; Mešić et al., 2022; Chejarla et al., 2022; Hadzikadunic et al., 2023; Özekenci, 2024; 2025). The data was obtained from the "*Connecting to Compete*" reports published by the World Bank (https://lpi.worldbank.org/report). The optimization of all criteria is benefit-oriented because it seeks to achieve maximum results. The LOPCOW-RAWEC method comprises two stages and eight steps. In the first stage, the four steps of the LOPCOW method are employed to weigh the criteria. In the second stage, the four steps of the RAWEC method are applied to rank the alternatives. After ranking the alternatives by years, the overall logistics performance of CEE countries is evaluated using the Borda Count method. Table 1 provides a summary of the criteria along with their descriptions. The decision matrix was also created using data gathered from the reports, as shown in Table 2.

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Table 1 | Overview of Criteria

Criteria	Abbr.	Optimization	Scale	Description
Customs	CUS	Benefit	From very low (1) to very high (5)	It measures the efficiency of customs and borders
Infrastructure	INF	Benefit		It measures the quality of trade and transport infrastructure
International Shipments	INS	Benefit		It focuses on the ease of arranging competitively priced shipments
Logistics Competence & Quality	LCQ	Benefit		It measures the competence and quality of logistics services
Timeliness	TIM	Benefit		It focuses on the frequency with which shipments reach consignees within scheduled or expected delivery times
Tracking & Tracing	TRA	Benefit		It measures the ability to track and trace consignments

Source: Arvis et al. (2023)

Table 2 | Decision Matrix (2023)

Alternatives	Abbr.	CUS	INF	INS	LCQ	TIM	TRA
Albania	ALB	2.40	2.70	2.80	2.30	2.50	2.30
Bosnia and Herzegovina	BIH	2.70	2.60	3.10	2.90	3.20	3.20
Bulgaria	BGR	3.10	3.10	3.00	3.30	3.50	3.30
Croatia	HRV	3.00	3.00	3.60	3.40	3.20	3.40
Czechia	CZE	3.00	3.00	3.40	3.60	3.70	3.20
Estonia	EST	3.20	3.50	3.40	3.70	4.10	3.80
Georgia	GEO	2.60	2.30	2.70	2.60	3.10	2.80
Hungary	HUN	2.70	3.10	3.40	3.10	3.60	3.40
Latvia	LVA	3.30	3.30	3.20	3.70	4.00	3.60
Lithuania	LTU	3.20	3.50	3.40	3.60	3.60	3.10
Moldova	MLD	1.90	1.90	2.70	2.80	3.00	2.80
Montenegro	MON	2.60	2.50	2.80	2.80	3.20	3.20
North Macedonia	NMA	3.10	3.00	2.80	3.20	3.50	3.20
Poland	POL	3.40	3.50	3.30	3.60	3.90	3.80
Romania	ROM	2.70	2.90	3.40	3.30	3.60	3.50
Serbia	SRB	2.20	2.40	2.90	2.70	3.40	2.90
Slovak Republic	SVK	3.20	3.30	3.00	3.40	3.50	3.30
Slovenia	SVN	3.40	3.60	3.40	3.30	3.30	3.00
Ukraine	UKR	2.40	2.40	2.80	2.60	3.10	2.60

Source: Arvis et al. (2023)

2.1 LOPCOW

The Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) method was introduced by Ecer and Pamucar in 2022. This method represents a new objective approach for establishing criteria weights. The application steps of the LOPCOW are as follows (Ecer & Pamucar, 2022):

Step 1. The decision matrix is formed.

Step 2. According to Eqs. (1–2), the decision matrix is normalized.

$$r_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}, \text{ if } j \text{ is a cost criterion} \quad (1)$$

$$r_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}, \text{ if } j \text{ is a benefit criterion} \quad (2)$$

Step 3. Percentage values (*PV*) of each criterion is determined based on Eq. (3).

$$PV_{ij} = \left| \ln \left(\frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^2}{m}}}{\sigma} \right) . 100 \right| \quad (3)$$

Step 4. Calculate the weights of the criteria using Eq. (4).

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \quad (4)$$

2.2 RAWEC

The Ranking of Alternatives with Weights of Criterion (RAWEC) method was developed by Puška et al. in 2024. This method simplifies the decision-making process by reducing the steps involved and eliminating complex calculations. The steps of the RAWEC method are as follows (Puška et al., 2024):

Step 1. The decision matrix is formed.

Step 2. According to Eqs. (5–6), the decision matrix is normalized using a double normalization approach.

$$n_{ij} = \frac{x_{ij}}{x_j\, max}, and\ n'_{ij} = \frac{x_j\, min}{x_{ij}}, for\ benefit\ criteria, and \quad (5)$$

$$n_{ij} = \frac{x_j\, min}{x_{ij}}, and\ n'_{ij} = \frac{x_{ij}}{x_j\, max}, for\ cost\ criteria. \quad (6)$$

Step 3. In this phase, the deviation from the criterion weight is calculated using Eqs. (7–8). This process effectively integrates the weighting of the normalized decision matrix with an evaluation of the deviation from the established criteria weights.

$$v_{ij} = \sum_{i=1}^{n} w_j . (1 - n_{ij}) \quad (7)$$

$$v'_{ij} = \sum_{i=1}^{n} w_j . (1 - n'_{ij}) \quad (8)$$

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Step 4. The final ranking of the alternatives is determined using Eq. (9).

$$Q_i = \frac{v'_{ij} - v_{ij}}{v'_{ij} + v_{ij}} \quad (9)$$

The RAWEC method generates a value between -1 and 1. The absolute magnitude of this value is used to assess the superiority of an alternative, with higher values indicating more favorable options. The alternative that achieves the highest value is regarded as the optimal choice.

2.3 Borda Count

The Borda Count method ranks alternatives in order of preference, from the most preferred to the least preferred. The alternative ranked lowest receives 0 points, the second lowest receives 1 point, and this pattern continues incrementally, with the highest-ranked alternative receiving points equal to the total number of alternatives. The points allocated to each alternative are then summed across all rankings, and the alternative with the highest total Borda count is considered the best option (Reilly, 2002).

3 Results

3.1 The results obtained from the LOPCOW method

The decision matrix was initially normalized using linear max-min normalization techniques, as described in Eqs. (1–2). Then, each criterion's percentage values (PV_{ij}) were calculated using Eq. (3). In this step, we calculated the mean square value of each criterion as a percentage of their standard deviations. This process helps eliminate the differences (gaps) caused by variations in data size. Subsequently, the final weights for the criteria were determined using Eq. (4). Table 3 presents the final ranking of the criteria over the years.

Table 3 | The criterion weights and final ranking (2010–2023)

Year	Criteria	CUS	INF	INS	LCQ	TIM	TRA	Ranking
2023	PV_{ij}	79.9126	76.1195	32.6825	69.6836	88.2970	82.1092	*TIM > TRA > CUS > INF > LCQ > INS*
	w_j	0.1864	0.1775	0.0762	0.1625	0.2059	0.1915	
	rank	3	4	6	5	1	2	
2018	PV_{ij}	39.5399	61.7089	61.9964	58.2041	45.9586	62.6173	*TRA > INS > INF > LCQ > TIM > CUS*
	w_j	0.1198	0.1870	0.1879	0.1764	0.1393	0.1897	
	rank	6	3	2	4	5	1	
2016	PV_{ij}	21.9971	50.4426	41.6206	59.8307	54.7199	54.4787	*LCQ > TIM > TRA > INF > INS > CUS*
	w_j	0.0777	0.1782	0.1470	0.2113	0.1933	0.1924	
	rank	6	4	5	1	2	3	
2014	PV_{ij}	55.9790	48.7563	84.5220	43.3906	65.2182	54.0951	*INS > TIM > CUS > TRA > INF > LCQ*
	w_j	0.1590	0.1385	0.2401	0.1233	0.1853	0.1537	
	rank	3	5	1	6	2	4	
2012	PV_{ij}	50.3038	47.1908	84.8193	85.1462	52.8031	53.9314	*LCQ > INS > TRA > TIM > CUS > INF*
	w_j	0.1344	0.1261	0.2267	0.2275	0.1411	0.1441	
	rank	5	6	2	1	4	3	
2010	PV_{ij}	31.6317	33.3545	57.5355	54.3395	52.9653	40.6692	*INS > LCQ > TIM > TRA > INF > CUS*
	w_j	0.1169	0.1233	0.2127	0.2009	0.1958	0.1504	
	rank	6	5	1	2	3	4	

Source: Author's calculation

The significance of criteria has evolved over the years. International shipments (INS) had a notable impact in earlier years, especially in 2010 and 2014, when it had the highest rank and largest weight of 0.2401 in 2014. However, by 2023, its importance had decreased, and it was ranked sixth. Logistics competence and quality (LCQ) was the most significant criterion in 2016 and 2012, ranking first with weights of 0.2113 and 0.2275, respectively. However, its impact declined in the following years. Tracking and tracing (TRA) have consistently ranked among the top three criteria in recent years (2018 and 2023), highlighting the increasing significance of logistics performance for global competitiveness. Customs (CUS) has consistently ranked low over the years, indicating its lesser influence than other criteria. The importance of infrastructure (INF) varied, typically ranking in the mid-level range. Timeliness (TIM) has consistently been influential from 2010 to 2023, ranking among the top three in many years with relatively high weights. After analyzing the importance of criteria over the years, the Borda counting method was employed to evaluate the overall importance of these criteria. Table 4 illustrates the results of the Borda Count method (R = rank, Sc = Score).

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Table 4 | Borda Count results (LOPCOW)

Criteria	2023		2018		2016		2014		2012		2010		Borda	
	R	Sc	R	Sc	R	Sc	R	Sc	R	Sc	R	Sc	Sc	R
CUS	3	3	6	0	6	0	3	3	5	1	6	0	7	6
INF	4	2	3	3	4	2	5	1	6	0	5	1	9	5
INS	6	0	2	4	5	1	1	5	2	4	1	5	19	1
LCQ	5	1	4	2	1	5	6	0	1	5	2	4	17	4
TIM	1	5	5	1	2	4	2	4	4	2	3	3	19	2
TRA	2	4	1	5	3	3	4	2	3	3	4	2	19	3

Source: Author's calculation

In the Borda method, each criterion is scored (between 0 and 5) based on its significance over the years. The results of the Borda count from 2010 to 2023 indicate that the most significant criteria were international shipments, timeliness, and tracking and tracing. In contrast, logistics competence and quality, infrastructure, and customs were considered the least important criteria during this period.

3.2 The results obtained from the RAWEC method

The decision matrix (Table 2) presents each alternative's maximum and minimum values based on specific criteria. This first step is essential as it enables distinct expressions during normalization. Following this, the decision matrix was subjected to double normalization using Eqs. (5–6), as illustrated in Tables 5 and 6. The calculation of criteria weights and deviations from maximum normalization values was combined using equations (7–8). The final ranking of the alternatives was determined through Eq. (9), as presented in Table 7. Considering the complex and detailed calculations required, this section will only showcase the results for the year 2023. The final values (Q_i) and the ranking order of alternatives for each year are illustrated in Table 8.

Table 5 | The normalized decision matrix (Type I)

Alternatives	CUS	INF	INS	LCQ	TIM	TRA
ALB	0.7059	0.7500	0.7778	0.6216	0.6098	0.6053
BIH	0.7941	0.7222	0.8611	0.7838	0.7805	0.8421
BGR	0.9118	0.8611	0.8333	0.8919	0.8537	0.8684
HRV	0.8824	0.8333	1.0000	0.9189	0.7805	0.8947
CZE	0.8824	0.8333	0.9444	0.9730	0.9024	0.8421
EST	0.9412	0.9722	0.9444	1.0000	1.0000	1.0000
GEO	0.7647	0.6389	0.7500	0.7027	0.7561	0.7368
HUN	0.7941	0.8611	0.9444	0.8378	0.8780	0.8947
LVA	0.9706	0.9167	0.8889	1.0000	0.9756	0.9474
LTU	0.9412	0.9722	0.9444	0.9730	0.8780	0.8158
MLD	0.5588	0.5278	0.7500	0.7568	0.7317	0.7368
MON	0.7647	0.6944	0.7778	0.7568	0.7805	0.8421
NMA	0.9118	0.8333	0.7778	0.8649	0.8537	0.8421
POL	1.0000	0.9722	0.9167	0.9730	0.9512	1.0000
ROM	0.7941	0.8056	0.9444	0.8919	0.8780	0.9211
SRB	0.6471	0.6667	0.8056	0.7297	0.8293	0.7632
SVK	0.9412	0.9167	0.8333	0.9189	0.8537	0.8684
SVN	1.0000	1.0000	0.9444	0.8919	0.8049	0.7895
UKR	0.7059	0.6667	0.7778	0.7027	0.7561	0.6842

Source: Author's calculation

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Table 6 | The normalized decision matrix (Type II)

Alternatives	CUS	INF	INS	LCQ	TIM	TRA
ALB	0.7917	0.7037	0.9643	1.0000	1.0000	1.0000
BIH	0.7037	0.7308	0.8710	0.7931	0.7813	0.7188
BGR	0.6129	0.6129	0.9000	0.6970	0.7143	0.6970
HRV	0.6333	0.6333	0.7500	0.6765	0.7813	0.6765
CZE	0.6333	0.6333	0.7941	0.6389	0.6757	0.7188
EST	0.5938	0.5429	0.7941	0.6216	0.6098	0.6053
GEO	0.7308	0.8261	1.0000	0.8846	0.8065	0.8214
HUN	0.7037	0.6129	0.7941	0.7419	0.6944	0.6765
LVA	0.5758	0.5758	0.8438	0.6216	0.6250	0.6389
LTU	0.5938	0.5429	0.7941	0.6389	0.6944	0.7419
MLD	1.0000	1.0000	1.0000	0.8214	0.8333	0.8214
MON	0.7308	0.7600	0.9643	0.8214	0.7813	0.7188
NMA	0.6129	0.6333	0.9643	0.7188	0.7143	0.7188
POL	0.5588	0.5429	0.8182	0.6389	0.6410	0.6053
ROM	0.7037	0.6552	0.7941	0.6970	0.6944	0.6571
SRB	0.8636	0.7917	0.9310	0.8519	0.7353	0.7931
SVK	0.5938	0.5758	0.9000	0.6765	0.7143	0.6970
SVN	0.5588	0.5278	0.7941	0.6970	0.7576	0.7667
UKR	0.7917	0.7917	0.9643	0.8846	0.8065	0.8846

Source: Author's calculation

Table 7 | Final ranking of alternatives

Alternatives	υ_{ij}	υ'_{ij}	Q_i	Rank
ALB	0.3336	0.0941	-0.5598	19
BIH	0.2088	0.2454	0.0804	13
BGR	0.1267	0.3146	0.4258	8
HRV	0.1300	0.3120	0.4117	9
CZE	0.1105	0.3284	0.4966	7
EST	0.0201	0.3900	0.9018	1
GEO	0.2759	0.1738	-0.2270	16
HUN	0.1389	0.3064	0.3763	11
LVA	0.0438	0.3741	0.7902	3
LTU	0.0849	0.3436	0.6037	4
MLD	0.3303	0.0975	-0.5440	18
MON	0.2300	0.2234	-0.0145	14
NMA	0.1453	0.2983	0.3450	12
POL	0.0257	0.3854	0.8749	2
ROM	0.1349	0.3099	0.3934	10
SRB	0.2642	0.1859	-0.1741	15
SVK	0.1070	0.3281	0.5083	6
SVN	0.1023	0.3256	0.5219	5
UKR	0.2899	0.1592	-0.2910	17

Source: Author's calculation

Table 8 | Logistics Performance of CEE Countries (2010–2023)

Alternatives	2023		2018		2016	
	Q_i	Rank	Q_i	Rank	Q_i	Rank
ALB	-0.5598	19	-0.3939	17	-0.6724	17
BIH	0.0804	13	-0.1729	14	-0.3722	15
BGR	0.4258	8	0.1256	9	-0.0748	11
HRV	0.4117	9	0.2136	7	0.3128	9
CZE	0.4966	7	0.9755	1	0.9043	1
EST	0.9018	1	0.4563	5	0.5194	5
GEO	-0.2270	16	-0.7728	18	-0.7575	19
HUN	0.3763	11	0.6170	3	0.6468	3
LVA	0.7902	3	-0.1422	12	0.5134	6
LTU	0.6037	4	0.0918	10	0.8707	2
MKD	-0.5440	18	-0.3036	16	-0.4691	16
MDA	-0.0145	14	-0.8025	19	-0.3288	14
MNE	0.3450	12	-0.2663	15	-0.7071	18

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POL	0.8749	2	0.7672	2	0.6092	4
ROM	0.3934	10	0.2465	6	0.1014	10
SRB	-0.1741	15	-0.1265	11	-0.1194	12
SVK	0.5083	6	0.1481	8	0.4837	7
SVN	0.5219	5	0.4699	4	0.3687	8
UKR	-0.2910	17	-0.1677	13	-0.1466	13

Alternatives	**2014**		**2012**		**2010**	
	Q_i	**Rank**	Q_i	**Rank**	Q_i	**Rank**
ALB	*	*	-0.1070	16	-0.6623	18
BIH	-0.3393	15	0.2289	8	-0.3165	14
BGR	0.3018	10	0.5617	3	-0.0113	10
HRV	0.1288	11	0.4511	6	-0.1364	12
CZE	0.7771	1	0.4883	5	0.9849	1
EST	0.5654	6	0.0556	11	0.4547	5
GEO	-0.8182	17	-0.0753	14	-0.3797	15
HUN	0.7194	3	0.5078	4	0.1798	7
LVA	0.6464	4	-0.0832	15	0.5854	3
LTU	0.3194	9	0.1662	10	0.4164	6
MKD	-0.8207	18	-0.3868	17	-0.1149	11
MDA	-0.4770	16	-0.9511	19	-0.4960	17
MNE	-0.0955	14	-0.6693	18	-0.7470	19
POL	0.7737	2	0.8845	1	0.7029	2
ROM	0.4295	8	0.2137	9	0.0017	9
SRB	-0.0087	13	-0.0309	13	-0.2558	13
SVK	0.4354	7	0.2879	7	0.5828	4
SVN	0.5719	5	0.6889	2	0.0374	8
UKR	0.0147	12	0.0373	12	-0.4283	16

Source: Author's calculation

The logistics performance of CEE countries over the years is illustrated above. Czechia (CZE) demonstrated strong performance by ranking first in 2010, 2014, 2016, and 2018. Poland (POL) consistently ranks among the top two, achieving its highest score of 0.8845 in 2012. Estonia (EST) stood out as the leading performer in 2023, achieving a score of 0.9018, highlighting a considerable improvement in logistics performance. Lithuania (LTU) showed significant progress over the years, achieving 2nd place in 2016 and 4th place in 2023, which reflects ongoing advancement in logistics performance. Slovakia (SVK) and Slovenia (SVN) have regularly achieved consistent outcomes, often ranking among the top 5–8. Georgia (GEO), Moldova (MLD), and North Macedonia (NMA) consistently ranked low, with negative scores throughout the period. Albania (ALB), although not ranked in 2014, continued to have negative scores, placing 17th to 19th. In 2023, Latvia (LVA) ranked 3rd,

but its performance fluctuated, showing negative scores and medium-level rankings in 2018 and 2012. Romania (ROM) has experienced moderate success, typically ranking between 6th and 10th place in most years. After analyzing the logistics performance of CEE countries over the years, the Borda counting method was employed to evaluate the overall performance of these countries. Table 9 demonstrates the results of the Borda Count method (*R* = rank, *Sc* = Score).

Table 9 | Borda Count results (RAWEC)

Alternatives	2023		2018		2016		2014		2012		2010		Borda	
	R	Sc	R	Sc	R	Sc	R	Sc	R	Sc	R	Sc	Sc	R
ALB	19	0	17	2	17	2	*	*	16	3	18	1	8	19
BIH	13	6	14	5	15	4	15	4	8	11	14	5	35	13
BGR	8	11	9	10	11	8	10	9	3	16	10	9	63	9
HRV	9	10	7	12	9	10	11	8	6	13	12	7	60	11
CZE	7	12	1	18	1	18	1	18	5	14	1	18	98	2
EST	1	18	5	14	5	14	6	13	11	8	5	14	81	5
GEO	16	3	18	1	19	0	17	2	14	5	15	4	15	17
HUN	11	8	3	16	3	16	3	16	4	15	7	12	83	3
LVA	3	16	12	7	6	13	4	15	15	4	3	16	71	8
LTU	4	15	10	9	2	17	9	10	10	9	6	13	73	7
MLD	18	1	16	3	16	3	18	1	17	2	11	8	18	15
MON	14	5	19	0	14	5	16	3	19	0	17	2	15	17
NMA	12	7	15	4	18	1	14	5	18	1	19	0	18	15
POL	2	17	2	17	4	15	2	17	1	18	2	17	101	1
ROM	10	9	6	13	10	9	8	11	9	10	9	10	62	10
SRB	15	4	11	8	12	7	13	6	13	6	13	6	37	12
SVK	6	13	8	11	7	12	7	12	7	12	4	15	75	6
SVN	5	14	4	15	8	11	5	14	2	17	8	11	82	4
UKR	17	2	13	6	13	6	12	7	12	7	16	3	31	14

Source: Author's calculation

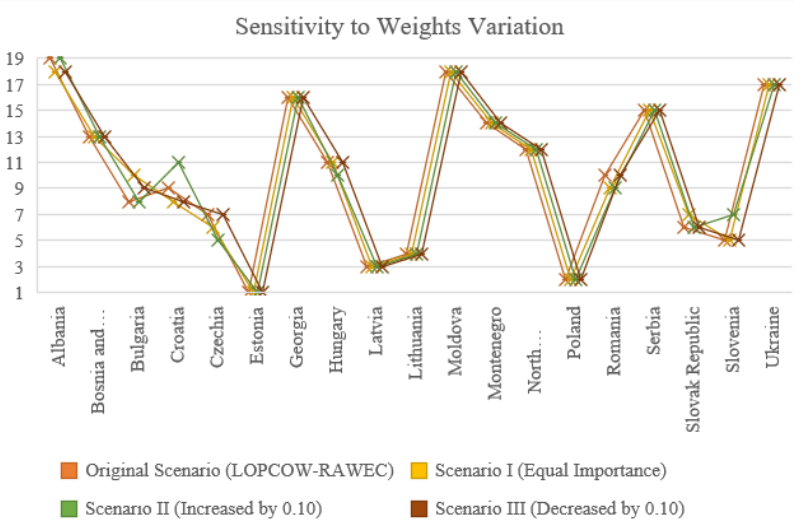
The Borda count results from 2010 to 2023 indicate that leaders from CEE countries such as Czechia, Poland, Hungary, Slovenia, and Estonia significantly demonstrated superior logistics performance compared to others, highlighting their strong logistics capabilities. Conversely, Balkan countries such as North Makedonia, Montenegro, Georgia, and Albania demonstrated inadequate logistics performance during this period.

3.3 Sensitivity Analysis

According to Demir et al. (2024), performing a sensitivity analysis is crucial for observing the robustness of the results. Sensitivity analyses are commonly used to validate the results in MCDM fields. Since the weight of the criteria significantly impacted the ranking, we tested variations in criterion weights across different scenarios. In the first scenario, all criteria

weights were assigned equal importance (0.166667). In the second scenario, we evaluated the stability of the rank in the MCDM model by adjusting the criteria weights either upward or downward. For instance, we used the “timeliness” criterion, the most important criterion, as our reference point. In this scenario, the coefficient for the timeliness criterion was slightly increased by 0.10 while the significance of the other criteria was decreased. Conversely, in another scenario, the coefficient for the timeliness criterion was reduced by 0.10 while the significance of the other criteria was increased. The rankings obtained from the aforementioned scenarios are presented in Figure 1.

Figure 1 | Sensitivity Results



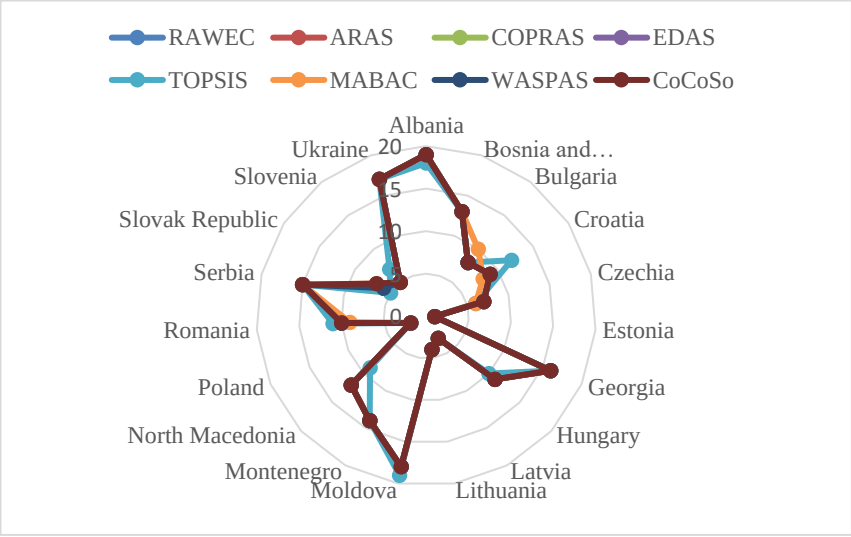
Source: Drawn by the author

The sensitivity results indicated that the minor weight adjustments did not change the ranking order, suggesting that the proposed model is robust to such adjustments. Comparative analyses are frequently employed in conjunction with sensitivity analysis in MCDM studies. Due to the diverse formulations and mathematical computations used in MCDM models, it is crucial to confirm the accuracy of the results by employing various methods (Ceballos et al., 2016; Pramanik et al., 2021).

3.4 Comparative Analysis

In this research, the validity of the LOPCOW-based RAWEC model was assessed through a comparative analysis employing different MCDM methods: ARAS, COPRAS, EDAS, TOPSIS, MABAC, WASPAS, and CoCoSo. Because of their distinct characteristics and calculations, the aforementioned methods are widely applied to address such complex problems (Mulliner et al., 2016; Bhaskar & Khan, 2022; Sampathkumar et al., 2023; Özekenci, 2023; Biswas et al., 2025). Figure 2 demonstrates the ranking order of alternatives obtained from the various MCDM methods.

Figure 2 | Comparison of MCDM methods



Source: Drawn by the author

A comparative analysis showed that the ranking order produced by the proposed model closely aligns with those generated by the ARAS, COPRAS, EDAS, TOPSIS, MABAC, WASPAS, and CoCoSo methods. The countries with the highest and lowest logistics performance in the CEE region remained consistent across all approaches. Specifically, Czechia, Poland, and Hungary ranked the highest in performance, whereas Georgia, Moldova, and North Macedonia ranked the lowest across all methods. Overall, it can be concluded that the findings confirm the reliability and robustness of the hybrid model.

Discussion and Conclusion

As Marti et al. (2014) points out, logistics plays a crucial role in international trade and greatly impacts bilateral trade volume. Effective logistics enhances competitiveness for both companies and countries, which are increasingly acknowledging its significance in global trade (Polat et al., 2023). According to Göçer et al. (2022), measuring logistics performance and developing strategies to enhance country performance is important. Furthermore, the LPI is increasingly recognized as a valuable tool that political authorities utilize more frequently to shape their strategies (Ojala & Celebi, 2015). This paper examines the logistics performance of CEE countries, specifically Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Estonia, Georgia, Hungary, Latvia, Lithuania, Moldova, Montenegro, North Macedonia, Poland, Romania, Serbia, Slovakia, Slovenia, and Ukraine, over the past few decades from 2010 to 2023. A hybrid model integrating the LOPCOW and RAWEC methods was proposed to accomplish this goal. Initially, the weights of the criteria were determined using the LOPCOW method. Subsequently, the logistics performance of the CEE countries was ranked using the RAWEC method. Finally, these countries' overall logistics performance was assessed by applying the Borda Count method.

The findings from the LOPCOW reveal that in 2023, timeliness (w_j = 0.2059*)* stood out as the most important criterion, while infrastructure (w_j = 0.0762) was the least important

criterion. Moreover, tracing and tracking (w_j = 0.1915) and customs (wj = 0.1864) played critical roles in effective logistics performance. In 2018, tracking and tracing (w_j = 0.1897) were recognized as the most significant factors, whereas customs (w_j = 0.1198) was considered the least significant criterion. Additionally, international shipments (w_j = 0.1879) and infrastructure (w_j = 0.1870) were important factors that significantly impacted logistics performance. Meanwhile, logistics competence and quality (w_j = 0.2113; w_j = 0.2275) were considered the top priorities in 2016 and 2012. Conversely, the least important criteria were customs (w_j = 0.0777) and infrastructure (w_j = 0.1261) during the relevant period. Furthermore, infrastructure (w_j = 0.2401; w_j = 0.2127) was highlighted as the key criterion in 2014 and 2010. On the other hand, logistics competence and quality (w_j = 0.1233) and customs (w_j = 0.1169) were determined as the least important criterion. The findings from 2010 to 2023 highlight that the most important criteria were international shipments, timeliness, and tracing and tracking. In contrast, logistics competence and quality, infrastructure, and customs were identified as the least important criteria. The findings reveal that the factors affecting logistics performance vary over time, with those highly significant in some years showing minimal impact in others. The current findings align with previous research (Bugarčić et al., 2020; Mešić et al., 2022; Hadzikadunic et al., 2023; Özekenci, 2024; Topal & Ulutaş, 2024; Akbulut et al.,2024), which indicates that international shipments, timeliness, and tracing and tracking indicators play a crucial role for improving the performance of the LPI. These findings may be explained by the fact that international shipments promote global trade and economic integration, allowing countries to engage in international markets effectively. Timeliness is crucial for ensuring that supply chain operations are efficient and meeting the demands of just-in-time production and delivery systems, essential for maintaining competitiveness. Tracing and tracking also enhance logistics transparency and reliability, enabling real-time monitoring and proactive management of potential disruptions. Together, these indicators contribute to the overall effectiveness and efficiency of a country's logistics performance, directly affecting its position in the global LPI.

The RAWEC findings reveal that in 2023, Estonia, Poland, Latvia, Lithuania, and Slovenia achieved the highest logistics performance, whereas Serbia, Georgia, Ukraine, Moldova, and Albania exhibited the lowest performance. In 2018, Czechia, Poland, Hungary, Slovenia, and Estonia demonstrated notable logistics performance, while North Macedonia, Moldova, Albania, Georgia, and Montenegro showed weak logistics performance. In 2016, Czechia, Lithuania, Hungary, Poland, and Estonia had the best logistics performance, while Bosnia and Herzegovina, Moldova, Albania, North Macedonia, and Georgia exhibited poor logistics performance. In 2014, Czechia, Poland, Hungary, Latvia, and Slovenia excelled in logistics performance, whereas North Macedonia, Bosnia and Herzegovina, Montenegro, Georgia, and Moldova displayed the worst logistics performance. In 2012, Poland, Slovenia, Bulgaria, Hungary, and Czechia performed notable logistics performance, while Latvia, Albania, Moldova, North Macedonia, and Montenegro demonstrated the lowest performance. In 2010, Czechia, Poland, Latvia, Slovakia, and Estonia achieved the highest logistics performance, while Georgia, Ukraine, Montenegro, Albania, and North Macedonia showed poor logistics performance. The overall performance of CEE countries indicated that Czechia, Poland, Hungary, Slovenia, and Estonia exhibited significantly better logistics

performance. In contrast, North Makedonia, Montenegro, Georgia, Moldova, and Albania reflected poor logistics performance from 2010 to 2023. This finding is supported by Isik et al. (2020), who discovered that Czechia, Poland, and Hungary were the top performers in logistics among CEE countries. Ju et al. (2024) indicate that Poland demonstrated significant logistics performance compared to other CEE countries. These findings may be explained by the fact that leader countries from the CEE region, such as Czechia, Poland, Hungary, Slovenia, and Estonia, play a privileged role in developing the logistics industry. These nations probably gained advantages from superior infrastructure, streamlined customs procedures, and cohesive supply chain systems, which played a role in their top positions for international shipments, timeliness, and tracking efficiency. In contrast, Balkan countries such as North Macedonia, Montenegro, Georgia, and Albania demonstrated poor logistics performance from 2010 to 2023, facing challenges like inadequate infrastructure, limited logistics competence, and inefficiencies in customs procedures. Additionally, the 2023 LPI highlights the Russia-Ukraine war's substantial effects on national and global logistics performance. Countries directly impacted by the conflict, such as Ukraine, have experienced a deterioration in their logistics capabilities. The LPI of Ukraine recorded a value of 2.74 in 2016, increased to 2.83 in 2018, and then declined to 2.7 in 2023. While there was improvement from 2016 to 2018, the aftermath of the COVID-19 pandemic and the ongoing Russia-Ukraine conflict have negatively influenced the overall index, leading to a decrease from 2.83 to 2.7.

Furthermore, sensitivity and comparative analysis are commonly utilized to assess the reliability of results in MCDM studies. In this context, a hybrid model was tested through sensitivity and comparative analysis. Firstly, a sensitivity analysis was conducted on variations in criterion weights across three different scenarios. Then, a comparative analysis was carried out to assess the stability of rankings across seven different MCDM methods. Consequently, the results from the sensitivity and comparative analysis confirmed the validity of the hybrid model. Several managerial implications are suggested based on the findings:

(i) CEE should prioritize the implementation of advanced tracking and tracing systems to enhance supply chain visibility and operational efficiency. Establishing partnerships with technology providers to adopt AI and IoT solutions will enable real-time tracking and help quickly address delays.
(ii) Governments and logistics firms ought to collaborate in order to improve international shipping procedures by enhancing operations at ports and terminals and minimizing turnaround times. In addition, creating trade agreements and bolstering alliances with international logistics centers can improve competitiveness.
(iii) Improving timeliness can be accomplished by utilizing modern route optimization software, investing in employee training to enhance scheduling accuracy, and developing contingency plans to manage disruptions caused by weather events or geopolitical tensions.
(iv) Countries in CEE can leverage shared knowledge and resources through regional collaboration. Joint ventures, collaborative infrastructure projects, and joint training programs can improve logistics efficiency across the region.
(v) Conducting regular benchmarking against leading logistics performers, such as Czechia, Poland, and Hungary, can offer valuable insights into areas that need improvement. Developing national logistics performance indicators that align with global standards can assist policymakers and industry stakeholders.

(vi) Sustainability is gaining significant importance in global logistics. Countries in CEE should promote the adoption of green logistics practices. These encompass the use of electric vehicles, the incorporation of renewable energy in warehouses, and the implementation of carbon offset programs. By embracing these initiatives, they can align with global environmental standards and strengthen their long-term competitiveness.

It is important to acknowledge the limitations of this study, even though it offers valuable insights into the logistics performance of CEE countries. While the analysis was conducted using six criteria, it may not encompass all aspects of performance evaluation. Future research could consider incorporating additional criteria. Furthermore, this study focuses solely on the logistics performance of CEE nations. Although it thoroughly assesses several selected countries, the applicability of its findings may be limited when considering other countries or sectors.

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