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Evaluating the Logistics Performance of G8 Nations Using Multi-Criteria Decision-Making Models

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Abstract: Logistics performance plays a pivotal role in fostering economic growth and enhancing global competitiveness. This study aims to evaluate the logistics performance of G8 nations through multi-criteria decision-making (MCDM) models. Standard Deviation (SD) has been applied to determine the weights of evaluation criteria, while the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN) has been employed to rank the countries based on their performance. The findings indicate that Timeliness emerges as the most critical factor influencing logistics efficiency. Among the G8 nations, Germany achieves the highest logistics performance, reflecting the robustness of its logistical infrastructure and operational efficiency. The results reinforce the premise that logistics performance is instrumental to both international trade and economic competitiveness. Nations demonstrating strong logistical capabilities are better positioned to excel in global markets, while those with underdeveloped logistics systems may face increased economic vulnerabilities. Enhancing logistical frameworks, including infrastructure and systems, is therefore essential for nations striving to improve their global standing. The insights presented underscore the importance of strategic investment in logistics infrastructure as a key policy instrument for enhancing economic resilience and international trade potential.

Keywords: Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN); G8; Logistics performance; Multi-criteria decision-making (MCDM); Standard Deviation (SD)

1 Introduction

Logistics has undergone significant advancements in history. It began with basic operations to carry goods between designated addresses in one direction and evolved into an international system of integrated multifaceted logistics networks and revolutions in technology. Increasing globalization has heightened the significance of logistics operations in global commerce, rendering it a pivotal factor in a nation's progress [1]. Consequently, there has been a demand for an approach to measure and evaluate the efficacy of logistics. For this purpose, in 2007, the World Bank established the Logistics Performance Index (LPI) as a means to evaluate the efficiency of nations in terms of logistics. It is an instrument specifically developed to assist nations in identifying the obstacles and prospects they encounter in their trade and logistics operations, while also providing suggestions on how countries might enhance their efficiency. It employs six fundamental variables to evaluate and classify nations based on their overall logistics performance [2]:

· The effectiveness of customs and border administration procedures.
· The standard of facilities pertaining to commerce and transportation.
· The convenience of organizing cost-effective global shipments.
· The proficiency and excellence of logistical services.
· The capability to monitor and follow shipments.
· The rate at which shipments are delivered to recipients within the designated or anticipated timeframe.

The logistics sector is experiencing rapid growth and has significant impacts on the financial state of nations. Assessing and appraising the logistics performance of nations can help them attain sustained advantages in competition by recognizing the advantages and disadvantages of logistics providers across the whole supply chain. The objective of this study is therefore to assess and prioritize the logistics performance of G8 nations.

Logistics performance evaluation involves the consideration of various factors that may clash with each other. Therefore, it is necessary to utilize methods that incorporate MCDM procedures. MCDM is a framework that allows for the identification of the most appropriate option from a set of established options when faced with several competing criteria.

There have been a few studies evaluated logistics performance with MCDM methods in the literature. Rezaei et al. [3] utilized the Best Worst Method (BWM) to determine the significances of six criteria employed by the World Bank in calculating LPI for various nations. Ulutaş and Karaköy [4] combined a subjective method called Stepwise Weight Assessment Ratio Analysis (SWARA) with an objective method known as Criteria Importance Through Intercriteria Correlation (CRITIC) to determine the weights of criteria. Alternatives are ranked by Proximity Indexed Value (PIV). This approach allows for a balanced consideration of the benefits and drawbacks of both weighting methods. Biswas and Anand [5] utilized Preference Selection Index (PSI) method and PIV methods to compare logistics performance of G7 and BRICS nations. Isik et al. [6] prioritized the logistics performance of 11 given nations in Central and Eastern Europe using Statistical Variance (SV) and Multi-Attributive Border Approximation Area Comparison (MABAC) approaches. Mercangoz et al. [7] utilized grey Complex Proportional Assessment (COPRAS-G) approach to evaluate the logistics performance ratings of 28 member states and five prospective nations for the European Union (EU). Yildirim and Mercangoz [8] examined and compared the logistical performance of OECD nations from 2010 to 2018 with the current LPI rankings using fuzzy Analytic Hierarchy Process (AHP) and grey Additive Ratio Assessment (ARAS). Ulutaş and Karaköy [9] used grey SWARA and grey Multi-Objective Optimization with Ratio Analysis (MOORA) methods to rank logistics performance of transition countries. Mešić et al. [10] assessed LPI of Western Balkan nations with CRITIC and Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) techniques. Çalık et al. [11] evaluated the logistics performance of OECD countries using AHP, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Combinative Distance-Based Assessment (CODAS) methods. Miškić et al. [12] created a comprehensive evaluation model for the LPI of EU nations using Method based on the Removal Effects of Criteria (MEREC) and Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS). Nevertheless, our understanding is that there is a limitation of research in the literature about the logistical performance assessment of G8 countries. Hadzikadunic et al. [13] examined the influence of weights of criterion on the calculation of overall LPI scores, utilizing CRITIC and Full Consistency Method (FUCOM) to calculate the weights, with MARCOS to assess the performance of EU nations. Özbek and Özekenci [14] assessed the success of the digital logistics market in emerging nations through integrated MCDM approaches using Logarithmic Percentage Change-driven Objective Weighting (LOPCOW) approach was employed to ascertain criteria weights, whereas the alternatives were ordered utilizing Multi Attribute Utility Theory (MAUT), TOPSIS, MARCOS, and Combined Compromise Solution (CoCoSo). Oğuz [15] evaluated the customs, facilities and logistics services provided by the most successful nations in the 2023 LPI using Evaluation based on Distance from Average Solution (EDAS) and TOPSIS methods. Çıray et al. [16] intended to provide a more precise and resilient technique for a comprehensive analysis of LPI using the World Bank's 2023 report with Entropy and Organisation, Rangement Et Synth&e De DonnCes Relarionnelles (ORESTE) method. Gürler et al. [17] employed 11 methodologies (ARAS, CoCoSo, CODAS, COPRAS, EDAS, Grey Relational Analysis (GRA), MABAC, MARCOS, MOORA, Operational Competitiveness Rating (OCRA), and Weighted Aggregated Sum Product Assessment (WASPAS)) to assess the logistics performance of EU members based on 33 factors to ensure robustness and uniformity. They also used Genetic Algorithms (GAs), CRITIC, Entropy, and Equal Weights to ascertain weights. Ju et al. [18] assessed LPI of EU countries using CRITIC and fuzzy Range of Value (ROV) methods.

The assessment framework that needs to be built has established goals that follow.

· To calculate the weights of the LPI with SD;
· To determine the logistics performance ranking of the G8 nations under evaluation with AROMAN;
· To offer managerial insights into the forthcoming model.

The primary contribution of this study lies in offering actionable insights for nations seeking to improve their logistics performance, thereby gaining a competitive advantage. These insights enable countries to allocate financial resources strategically based on the study's recommendations. As a result, the proposed strategies may yield economic benefits by enhancing logistical efficiency.

This study is organized into six sections. The following section outlines the methodology employed. The "Results" section presents the analysis findings, including the criteria weights determined through the SD method and the rankings of alternatives generated by the AROMAN approach. The "Conclusion" section summarizes the key findings and offers recommendations for future research directions.

2 Methodology

This section explains the use of the SD method for determining the criteria weights and the AROMAN approach for ranking the alternatives.

2.1 SD

SD is an objective method to calculate criteria weights in MCDM. It uses following steps to calculate the weights of the criteria based on their respective SDs [19].

Step 1: The decision matrix is arranged. Eq. (1) illustrates the decision matrix (A).

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

Step 2: The decision matrix is normalized according to Eq. (2).

$$k_{ij} = \frac{a_{ij} - \min\limits_{i} a_{ij}}{\max\limits_{i} a_{ij} - \min\limits_{i} a_{ij}} \tag{2}$$

Step 3: The criteria weights are derived from Eq. (3).

$$w_j = \frac{s_j}{\sum_{j=1}^{n} s_j}, \quad j = 1, 2, \quad \ldots, \quad n \tag{3}$$

where, s_j denotes the SD of the $j-$th criterion and it can be obtained using Eq. (4).

$$s_j = \sqrt{\frac{\sum_{i=1}^{m} \left(k_{ij} - \bar{k}_j\right)^2}{m}}, \quad j = 1, 2, \quad \ldots, \quad n \tag{4}$$

2.2 AROMAN

This novel method, recently developed by Bošković et al. [20, 21], combines vector and linear normalization techniques to deliver precise data structures that can be used for further computations.

Step 1: A decision matrix is constructed, as presented in Eq. (1).

Step 2: The data in decision matrix are normalized with Eqs. (2) (linear) and (5) (vector).

$$k_{ij}^{*} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \tag{5}$$

Step 3: Eq. (6) is used to compute the aggregated normalization.

$$k_{ij}^{norm} = \frac{\beta k_{ij} + (1 - \beta) k_{ij}^{*}}{2} \tag{6}$$

In Eq. (6), β represents the aggregated averaged normalization, which is set to 0.5 for this study.

Step 4: Eq. (7) is used to compute the weighted normalization.

$$\bar{k}_{ij} = w_i \cdot k_{ij}^{\text{norm}} \tag{7}$$

Step 5: Eq. (8) is used to sum the weighted normalized scores for the beneficial criteria.

$$B_i = \sum_{j=1}^{n} \bar{k}_{ij}^{(\max)} \tag{8}$$

Step 6: Eq. (9) is used to determine the final ranking of the available options.

$$F_i = e^{\left(B_i{}^{(\lambda)}\right)} \tag{9}$$

3 Results

The primary objective of this study is to evaluate the logistics performance of G8 nations. A decision matrix, consisting of countries and LPI criteria, is constructed. The decision matrix is presented in Table 1.

Table 1. Decision matrix

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	4	4.3	3.6
France	3.7	3.8	3.7
Germany	3.9	4.3	3.7
Italy	3.4	3.8	3.4
Japan	3.9	4.2	3.3
Russia	2.4	2.7	2.3
United Kingdom	3.5	3.7	3.5
United States	3.7	3.9	3.4
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	4.2	4.1	4.1
France	3.8	4	4.1
Germany	4.2	4.2	4.1
Italy	3.8	3.9	3.9
Japan	4.1	4	4
Russia	2.6	2.6	2.9
United Kingdom	3.7	4	3.7
United States	3.9	4.2	3.8

This decision matrix is normalized using Eq. (2). Table 2 indicates the normalized matrix.

The weights of the criteria are determined using Eq. (3) according to the SD method. Table 3 demonstrates the weights of the criteria.

Table 2. The normalized matrix

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	1	1	0.929
France	0.813	0.688	1
Germany	0.938	1	1
Italy	0.625	0.688	0.786
Japan	0.938	0.938	0.714
Russia	0	0	0
United Kingdom	0.688	0.625	0.857
United States	0.813	0.75	0.786
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	1	0.938	1
France	0.750	0.875	1
Germany	1	1	1
Italy	0.750	0.813	0.833
Japan	0.938	0.875	0.917
Russia	0	0	0
United Kingdom	0.688	0.875	0.667
United States	0.813	1	0.750

According to the results of the SD method, the criteria are ranked by weight as follows: Timeliness, Tracking & Tracing, Infrastructure, International Shipments, Logistics Competence, and Customs. The AROMAN method is applied to determine the rankings of the countries. The decision matrix serves as the initial step of the AROMAN method and is presented in Table 1. Normalization of the decision matrix is performed using Eq. (2) and Eq. (5). The outcomes of normalization with Eq. (2) are provided in Table 4, while the results using Eq. (5) are shown in Table 5.

The resultant normalized values are integrated using Eq. (6). The outcomes of the amalgamation are displayed in Table 6.

Table 3. The weights of the criteria

Countries \ Criteria	Customs	Infrastructure	International Shipments
w_j	0.164	0.166	0.166
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
w_j	0.165	0.168	0.172

Table 4. The normalized matrix (linear normalization)

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	1	1	0.929
France	0.813	0.688	1
Germany	0.938	1	1
Italy	0.625	0.688	0.786
Japan	0.938	0.938	0.714
Russia	0	0	0
United Kingdom	0.688	0.625	0.857
United States	0.813	0.750	0.786
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	1	0.938	1
France	0.750	0.875	1
Germany	1	1	1
Italy	0.750	0.813	0.833
Japan	0.938	0.875	0.917
Russia	0	0	0
United Kingdom	0.688	0.875	0.667
United States	0.813	1	0.750

Table 5. The normalized matrix (vector normalization)

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	0.393	0.393	0.376
France	0.364	0.347	0.386
Germany	0.384	0.393	0.386
Italy	0.334	0.347	0.355
Japan	0.384	0.384	0.344
Russia	0.236	0.247	0.24
United Kingdom	0.344	0.338	0.365
United States	0.364	0.356	0.355
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	0.389	0.371	0.377
France	0.352	0.362	0.377
Germany	0.389	0.38	0.377
Italy	0.352	0.353	0.359
Japan	0.38	0.362	0.368
Russia	0.241	0.235	0.267
United Kingdom	0.343	0.362	0.34
United States	0.361	0.38	0.35

Table 6. The aggregated normalized values

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	0.348	0.348	0.326
France	0.294	0.259	0.347
Germany	0.331	0.348	0.347
Italy	0.24	0.259	0.285
Japan	0.331	0.331	0.265
Russia	0.059	0.062	0.06
United Kingdom	0.258	0.241	0.306
United States	0.294	0.277	0.285
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	0.347	0.327	0.344
France	0.276	0.309	0.344
Germany	0.347	0.345	0.344
Italy	0.276	0.292	0.298
Japan	0.33	0.309	0.321
Russia	0.06	0.059	0.067
United Kingdom	0.258	0.309	0.252
United States	0.294	0.345	0.275

Table 7. The weighted normalized values

Countries \ Criteria	Customs	Infrastructure	International Shipments
Canada	0.057	0.058	0.054
France	0.048	0.043	0.058
Germany	0.054	0.058	0.058
Italy	0.039	0.043	0.047
Japan	0.054	0.055	0.044
Russia	0.01	0.01	0.01
United Kingdom	0.042	0.04	0.051
United States	0.048	0.046	0.047
Countries \ Criteria	**Logistics Competence**	**Tracking & Tracing**	**Timeliness**
Canada	0.057	0.055	0.059
France	0.046	0.052	0.059
Germany	0.057	0.058	0.059
Italy	0.046	0.049	0.051
Japan	0.054	0.052	0.055
Russia	0.01	0.01	0.012
United Kingdom	0.043	0.052	0.043
United States	0.049	0.058	0.047

Table 8. The results of AROMAN method

Countries \ Criteria	B_i	F_i	Rankings
Canada	0.340	1.405	2
France	0.306	1.358	4
Germany	0.344	1.411	1
Italy	0.275	1.317	6
Japan	0.314	1.369	3
Russia	0.062	1.064	8
United Kingdom	0.271	1.311	7
United States	0.295	1.343	5

Eq. (7) provides the weighted normalized values, which are presented in Table 7.

The weighted normalized values are aggregated using Eq. (8), and the rankings of the countries are derived from Eq. (9). The results, along with the country rankings, are presented in Table 8.

Based on the results of the AROMAN method, the countries are ranked as follows: Germany, Canada, Japan, France, the United States, Italy, the United Kingdom, and Russia. To evaluate the accuracy of the AROMAN method, its results are compared with those obtained from other MCDM methods, including COPRAS, ARAS, WASPAS, and MARCOS. All MCDM methods employed produced rankings identical to those generated by the AROMAN method. Therefore, it is concluded that the AROMAN method yields accurate findings.

4 Discussion

In this study, the SD and AROMAN methods were employed to evaluate the logistics capabilities of G8 nations, yielding reliable and trustworthy outcomes. The AROMAN method produced results that were consistent with those obtained from other MCDM methods, including COPRAS, ARAS, WASPAS, and MARCOS. This consistency indicates that the AROMAN method is a dependable tool for assessing logistics performance.

The findings reveal that Germany possesses the most efficient logistics system among the G8 nations, reflecting its superior quality in logistics services, customs clearance, and infrastructure. Conversely, Russia ranks lowest, highlighting the significant potential for improvement within its logistics systems and the logistical challenges it faces. This underscores the necessity for countries like Russia to make strategic investments aimed at enhancing their logistics networks.

This study serves as a valuable resource for policymakers and managers interested in improving the logistics sector through comparative analyses of national logistics performance. The results can assist G8 countries in formulating strategies for optimizing resource allocation, given that logistics performance significantly influences economic growth and competitiveness.

Future research could further explore the impact of logistics performance across various sectors and industries. Additionally, integrating the AROMAN method with other MCDM approaches may enhance the literature in this field and provide insights into logistics performance improvements in different countries. Such developments can help nations create a competitive advantage in global commerce by optimizing their logistics capabilities.

5 Conclusions

This study presents a comprehensive analysis of the logistics performance of G8 countries, employing the SD and AROMAN methods for evaluation and ranking. The findings from the SD method indicate the following ranking of LPI criteria based on their weights: Timeliness, Tracking & Tracing, Infrastructure, International Shipments, Logistics Competence, and Customs. In terms of logistics efficacy, Germany is ranked highest, while Russia ranks lowest. The results of the AROMAN method are consistent with those obtained from other MCDM methods, including COPRAS, ARAS, WASPAS, and MARCOS, demonstrating the reliability and validity of the AROMAN method in evaluating logistics performance.

Logistics performance is a critical determinant of a nation's economic competitiveness and its ability to engage in global trade, a finding that is supported by the results of this study. Consequently, nations can enhance their competitiveness in the global marketplace by optimizing their logistics systems. Specifically, countries with inadequate logistics performance are at risk of increased vulnerabilities in this domain and should consider investing in their logistics infrastructure and processes.

It is recommended that future research explore the logistics performance of countries across distinct geographical regions and examine the impact of this performance on various economic and social indicators in greater detail. Such research will facilitate the development of strategies aimed at improving logistics performance, ultimately contributing to the more sustainable and efficient management of global supply chains.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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Nomenclature

AHP	Analytic Hierarchy Process
ARAS	Additive Ratio Assessment
AROMAN	Alternative Ranking Order Method Accounting for Two-Step Normalization
BWM	Best Worst Method
CoCoSo	A Combined Compromise Solution
CODAS	Combinative Distance-Based Assessment
COPRAS	Complex Proportional Assessment
CRITIC	Criteria Importance Through Intercriteria Correlation
EDAS	Evaluation Based on Distance from Average Solution
EU	European Union
FUCOM	Full Consistency Method
GAs	Genetic Algorithms
GRA	Grey Relational Analysis
LOPCOW	Logarithmic Percentage Change-driven Objective Weighting
LPI	Logistics Performance Index
MABAC	Multi-Attributive Border Approximation Area Comparison
MARCOS	Measurement of Alternatives and Ranking according to Compromise Solution
MCDM	Multi Criteria Decision Making
MEREC	Method Based on the Removal Effects of Criteria
MOORA	Multi-Objective Optimization with Ratio Analysis
MAUT	Multi Attribute Utility Theory
OCRA	Operational Competitiveness Rating
ORESTE	Organisation, Rangement Et Synth&e De DonnCes Relarionnelles
PIV	Proximity Indexed Value
ROV	Range of Value
SD	Standard Deviation
SWARA	Stepwise Weight Assessment Ratio Analysis
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	Vise Kriterijumska Optimizacija I Kompromisno Resenje
WASPAS	Weighted Aggregated Sum Product Assessment