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Measuring Logistics Performance in Emerging Economies: Insights from the SITDE–MABAC Method

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Abstract: Enhancing logistics performance has been widely recognized as a critical pathway for accelerating economic development in emerging economies. In this context, a rigorous and objective assessment of national logistics performance remains essential. Accordingly, an integrated multi-criteria decision-making (MCDM) framework based on the Skewness Impact Through Distributional Evaluation (SITDE) method and the Multi-Attributive Border Approximation Area Comparison (MABAC) method was proposed for the systematic evaluation of logistics performance across the Emerging Seven (E7) economies. Within this framework, criterion weights were objectively derived using the SITDE method by capturing the distributional characteristics and skewness effects inherent in logistics performance indicators, thereby minimizing subjectivity in the weighting process. Subsequently, the MABAC method was employed to rank countries by quantifying their distances from criterion-specific boundary approximation areas. The empirical analysis focused on the E7 countries—China, India, Brazil, Russia, Indonesia, Mexico, and Türkiye—using the Logistics Performance Index (LPI) indicators obtained from the World Bank database. The results demonstrated that timeliness emerged as the most influential determinant of overall logistics performance. Among the E7 countries, China was identified as exhibiting the highest logistics performance, whereas Russia recorded the lowest performance level. Notably, Türkiye was ranked second, despite its comparatively lower level of economic development relative to several other E7 economies. The robustness and stability of the proposed SITDE–MABAC framework were further confirmed through comprehensive sensitivity and comparative analyses. Beyond methodological advancement, the findings offer important managerial, policy-oriented, and region-specific insights, providing evidence-based guidance for policymakers and logistics practitioners seeking to enhance logistics efficiency, resilience, and international competitiveness in developing economies.

Keywords: Logistics performance; E7 countries; MCDM; SITDE method; MABAC method

1 Introduction

Logistics is the process of ensuring that the right product or service is delivered to the right place at the right time in optimal condition. In recent years, the global logistics industry has experienced significant growth, becoming a vital component of the economic system and a major force in the global economy. Efficient logistics operations are crucial for driving economic growth, enhancing productivity, and improving a country's competitiveness, while also serving as a significant source of employment [1]. The ongoing expansion of global trade, together with nations' aspirations to enhance their integration into the international trading system, relies not only on sustaining an open global economic framework but also on improving the quality and efficiency of critical supporting infrastructures, such as logistics services. Inadequate logistics services (such as poor coordination of border procedures, inefficiencies in customs clearance at ports, fragmented and insufficient transportation infrastructure, high transportation costs, delays in shipment tracking and tracing, terminal handling delays, insufficient cold storage facilities at ports, and challenges in certifying product quality) can significantly hinder international trade [2]. As logistics and transportation become increasingly vital to global trade, the Logistics Performance Index (LPI) was developed to evaluate disparities among nations regarding customs procedures, logistics costs, and the quality of infrastructure for both overland and maritime transport [3].

The LPI is an interactive benchmarking tool created by the World Bank based on a 2007 global survey, facilitating comparisons among 139 countries. It assesses logistics performance across six key components: (1) the efficiency of customs and border management clearance ("customs"); (2) the quality of trade and transport infrastructure ("infrastructure"); (3) the ease of arranging competitively priced shipments ("international shipments"); (4) the competence and quality of logistics services ("quality and competence of services"); (5) the capability to track and trace consignments ("tracking and tracing"); and (6) the consistency with which shipments reach consignees within scheduled or expected delivery times ("timeliness") [4]. Understanding the dynamics and sensitivity of these rankings is essential for improving logistics efficiency and competitiveness at both national and regional levels [5]. The Emerging Seven (E7) countries (China, India, Brazil, Russia, Indonesia, Mexico, and Türkiye) represent significant emerging economies that play a crucial role in global trade and supply chains. Their rapid economic growth, combined with varying infrastructure standards, customs procedures, and trade policies, underscores the importance of logistics efficiency in enhancing competitiveness. Analyzing the LPI within the context of the E7 provides valuable insights into how these major emerging markets can improve their logistical capabilities to promote sustainable economic development.

The motivation for this study arises from the need to evaluate and compare the logistics performance levels of the E7 countries. Understanding their logistics performance provides insights into operational capabilities, competitiveness, and areas requiring improvement. The primary aim of this research is to propose a robust multi-criteria decision-making (MCDM) methodology for systematically assessing and comparing logistics performance in developing countries. In this context, the Skewness Impact Through Distributional Evaluation and Multi-Attributive Border Approximation Area Comparison (SITDE–MABAC) method was introduced as an effective tool for logistics performance analysis. The SITDE method [6] was used for objective criteria weighting, determining weights based on the skewness of the criteria to ensure an unbiased and data-driven approach. Subsequently, the MABAC method [7] ranked countries by calculating the distances of alternatives from criterion-based boundary approximation areas, providing a structured and reliable performance evaluation.

The empirical application focused on the E7 countries due to the critical role of logistics performance in supporting their economic growth. Analyzing logistics performance among the E7 nations also provides insight into their competitive positioning, highlighting both strengths and weaknesses. The results indicate that China achieves the highest logistics performance, while Russia exhibits the lowest. A notable finding is that Türkiye, despite a lower level of economic development, ranks second in logistics performance, demonstrating the importance of efficient logistics operations in emerging economies.

The contributions of this study are twofold. First, it demonstrates the robustness of the SITDE–MABAC method through sensitivity and comparison analyses. Sensitivity analysis confirms that China consistently maintains the top position across all scenarios. Comparison analysis conducted using alternative MCDM methods, including Aczel-Alsina Weighted ASsessment (ALWAS) [8], Alternative Ranking Technique based on Adaptive Standardized Intervals (ARTASI) [9], Measurement of Alternatives and Ranking according to the Compromise Solution (MARCOS) [10], Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [11], and Weighted Aggregated Sum Product ASsessment (WASPAS) [12], shows consistent rankings and near-perfect correlations, validating the reliability of the results. Second, the study provides a comprehensive comparison of logistics performance across the E7 countries, offering practical insights and recommendations for enhancing logistics systems in emerging economies. This research not only advances the methodological application of SITDE–MABAC in logistics performance evaluation but also informs policymakers and stakeholders on strategic areas for improving logistics efficiency and competitiveness.

2 Literature Review

In today's business environment, a competitive and efficient logistics system is critical for driving economic growth and achieving a strategic advantage in both regional and global markets. High levels of logistics performance not only improve operational outcomes for individual firms but also enhance the overall efficiency of a country's logistics infrastructure [13]. Accordingly, assessing logistics performance has long been a focus of research, with recent studies increasingly employing MCDM approaches to systematically evaluate and compare logistics systems across countries [14]. Several studies have investigated the logistics performance of countries or regional groups using various MCDM methods. Isik et al. [15] analyzed logistics performance in Central and Eastern Europe with the Statistical Variance (SV) and MABAC methods, identifying timeliness as the most important criterion and infrastructure as the least critical. The top-ranked countries were the Czech Republic, Poland, and Hungary. Senir [16] examined Türkiye and European Union (EU) countries using Criteria Importance Through Intercriteria Correlation (CRITIC) and COmplex PRoportional ASsessment (COPRAS), finding customs to be the most critical criterion, with the Netherlands leading in performance. Kargı [17] assessed Organization for Economic Co-operation and Development (OECD) countries via entropy and WASPAS methods, highlighting infrastructure as the most significant factor, positioning Germany at the top. Mešić et al. [18] evaluated the Western Balkan countries using CRITIC and MARCOS, underscoring timeliness as essential, with Serbia achieving the highest ranking.

Miškić et al. [19] applied an integrated method based on the Removal Effects of Criteria (MEREC)-MARCOS model to EU countries, ranking Germany highest, while Hadzikadunic et al. [20] employed the CRITIC-Full Consistency Method (FUCOM) and MARCOS, identifying Finland as the leading country. Çıray et al. [21] analyzed global economies using entropy-based ORESTE, highlighting infrastructure, with Singapore performing best. Özekenci [22] assessed the Organization of the Petroleum Exporting Countries (OPEC) using entropy, CRITIC, and Logarithmic Percentage Change-driven Objective Weighting (LOPCOW)-based Evaluation based on Distance from Average Solution (EDAS), finding infrastructure, international shipments, and timeliness critical, with the United Arab Emirates (UAE) ranking highest. Topal and Ulutaş [23] examined G8 countries with Standard Deviation (SD) and Alternative Ranking Order Method Accounting for Normalization (AROMAN) methods, emphasizing timeliness, with Germany at the top. Further research includes the study by Akbulut et al. [24], who evaluated G20 logistics performance using SD, Preference Selection Index (PSI), and MEREC-based Matrix Approach to Robustness Analysis (MARA), identifying customs as the most essential criterion, again highlighting Germany's leading position. Gelmez et al. [25] applied SD-based COPRAS and SAW to G20 nations, confirming Germany's top ranking. Özekenci [26] evaluated OECD countries using SD, CRITIC, LOPCOW, MEREC, and Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) methods, noting tracking and tracing as critical, with Finland leading. Özdıl et al. [27] assessed 27 EU countries using LOPCOW and EDAS, identifying Germany as the top performer and Bulgaria as the lowest performer from 2007 to 2023. Finally, Silva et al. [5] applied CRITIC, MARCOS, TOPSIS, and SAW to European nations, reaffirming Finland's notable logistics performance ranking.

Table 1. Literature review

Research	Country/Region	MCDM Methods	Key Criteria Identified	Top-Ranked Country
Isik et al. [15]	Central & Eastern Europe	SV and MABAC	Timeliness	Czech Republic
Senir [16]	Türkiye & EU	CRITIC and COPRAS	Customs	Netherlands
Kargı [17]	OECD	Entropy and WASPAS	Infrastructure	Germany
Mešić et al. [18]	Western Balkans	CRITIC and MARCOS	Timeliness	Serbia
Miškić et al. [19]	EU	MEREC and MARCOS	Various	Germany
Hadzikadunic et al. [20]	EU	CRITIC-FUCOM and MARCOS	Various	Finland
Cıray et al. [21]	Global	Entropy-based ORESTE	Infrastructure	Singapore
Özekenci [22]	OPEC	Entropy, CRITIC, and LOPCOW-EDAS	Infrastructure, international shipments, and timeliness	UAE
Topal and Ulutaş [23]	G8	SD and AROMAN	Timeliness	Germany
Akbulut et al. [24]	G20	SD, PSI, and MERECMARA	Customs	Germany
Gelmez et al. [25]	G20	SD-based COPRAS and SAW	Various	Germany
Özekenci [26]	OECD	SD, CRITIC, LOPCOW, MEREC, and CRADIS	Tracking & tracing	Finland
Özdıl et al. [27]	EU-27	LOPCOW and EDAS	Various	Germany
Silva et al. [5]	Europe	CRITIC, MARCOS, TOPSIS, and SAW	Various	Finland

These studies highlight several key insights. Infrastructure, timeliness, customs, and tracking & tracing repeatedly emerge as critical logistics performance criteria across regions and country groups. Moreover, Germany, Finland, and other leading nations consistently rank highly, emphasizing the importance of robust logistics systems in supporting economic competitiveness. Table 1 illustrates a comprehensive overview of previous studies that have employed

MCDM approaches to assess and compare logistics performance across countries and regions.

3 Methodological Framework: The SITDE–MABAC Method

In this study, the SITDE–MABAC method was proposed to determine the logistics performance levels of the E7 country group, which represents a group of emerging economies. This method integrates objective criteria weighting and alternative ranking approaches. In this section, the procedural steps of the SITDE–MABAC method are explained. For the application of this method, countries $L = \{L_1, L_2, \ldots, L_d, \ldots, L_D\}\,(d = 1, 2, \ldots, D)$ and logistics performance criteria $x = \{x_1, x_2, \ldots, x_h, \ldots, x_H\}\,(h = 1, 2, \ldots, H)$ were first defined within the decision-making model. Subsequently, the method was implemented in two stages. In Stage 1, the SITDE method was employed to determine the weights of the logistics performance criteria. In Stage 2, the MABAC method was applied to ranked countries according to their logistics performance levels by considering the weighted criteria. The notations used in the SITDE–MABAC method are presented in the Appendix, and the methodological steps are described as follows.

Stage 1: Weight vector estimation of logistics performance criteria using SITDE

Step 1: To determine the objective criteria of the weight vector, the initial decision matrix ($O = [O_{dh}]_{DH}$) must first be constructed. The initial matrix represents the logistics performance criterion values for each country. Eq. (1) presents the initial decision matrix, where O_{dh} denotes the value of the d-th alternative with respect to the h-th criterion:

$$O = \begin{bmatrix} O_{11} & \cdots & O_{1h} & \cdots & O_{1H} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ O_{d1} & \cdots & O_{dh} & \cdots & O_{dH} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ O_{D1} & \cdots & O_{Dh} & \cdots & O_{DH} \end{bmatrix}; (d = 1, 2, \ldots, D; h = 1, 2, \ldots, H) \tag{1}$$

Step 2: In the second step of the SITDE method, the initial decision matrix is normalized. In this step, a max-min-based normalization approach is employed. The normalized matrix ($N = [N_{dh}]_{DH}$) is constructed, as shown in Eq. (2):

$$N_{dh} = \begin{cases} \frac{\min\limits_d (O_{dh})}{O_{dh}} \text{ for } h \in \boldsymbol{x}^+ \\ \frac{O_{dh}}{\max\limits_d (O_{dh})} \text{ for } h \in \boldsymbol{x}^- \end{cases}; (d = 1, 2, \ldots, D; h = 1, 2, \ldots, H) \tag{2}$$

Step 3: In the third step, criterion-based skewness values are calculated, and the skewness vector ($S = [S_h]_H$) is constructed. This vector is determined using Eq. (3), which incorporates the SD (σ_h) and mean values ($\overline{N}_h$) of the criteria. Since the SITDE method aims to derive the criteria weight vector based on skewness values, this step is essential to the application of the method:

$$S_h = \frac{D}{(D-1)(D-2)} \sum_{d=1}^{D} \left(\frac{N_{dh} - \overline{N}_h}{\sigma_h} \right)^3; (d = 1, 2, \ldots, D; h = 1, 2, \ldots, H) \tag{3}$$

Step 4: Based on the skewness vector, a normalization process is performed using logarithmic operations to obtain a vector representing the logarithmic values of the criteria ($L = [L_h]_H$). This process is calculated using Eq. (4):

$$L_h = \log \left| \left((S_h + 1) + \left(|\min_h (S_h)| + 1 \right) \right) \right|; \quad (h = 1, 2, \ldots, H) \tag{4}$$

Step 5: To finalize the criteria weights, a linear normalization procedure is applied, through which the logistics performance criteria weights ($W = [W_h]_H$) are obtained, as shown in Eq. (5):

$$W_h = \frac{L_h}{\sum_{h=1}^{H} L_h}; \quad (h = 1, 2, \ldots, H) \tag{5}$$

where, W_h represent the weight of the h-th logistics performance criterion. The criteria weight vector is defined as $W = (W_1, W_2, \ldots, W_H)$, subject to the normalization condition: $\sum_{h=1}^{H} W_h = 1$ and $W_h \geq 0\ \forall h$.

Stage 2: Rank vector estimation of countries using MABAC

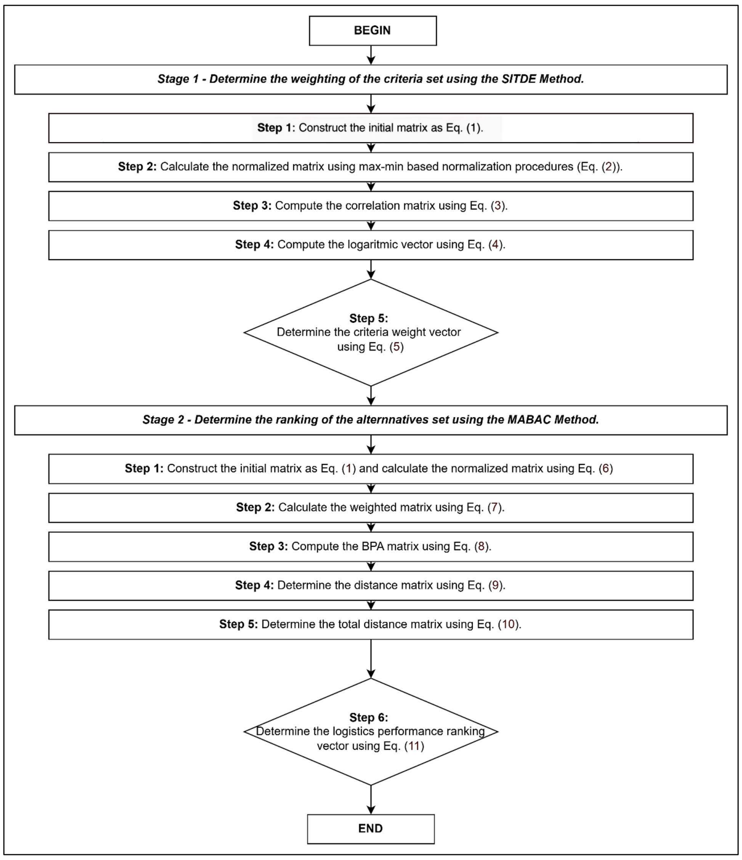

Figure 1. Flowchart of the SITDE–MABAC method for each country's logistics performance assessment

Step 1: The initial decision matrix ($O = [O_{dh}]_{DH}$) used in the SITDE criteria weighing method is also adopted as the initial matrix in the MABAC method. As shown in Eq. (6), a max-min distance-based normalization procedure is applied to obtain the normalized decision matrix ($M = [M_{dh}]_{DH}$):

$$M_{dh} = \begin{cases} \frac{O_{dh} - \min_d(O_{dh})}{\max_d(O_{dh}) - \min_d(O_{dh})} & \text{for } h \in \boldsymbol{x}^+ \\ \frac{O_{dh} - \max_d(O_{dh})}{\max_d(O_{dh}) - \min_d(O_{dh})} & \text{for } h \in \boldsymbol{x}^- \end{cases}; \quad (d = 1, 2, \ldots, D;\ h = 1, 2, \ldots, H) \tag{6}$$

Step 2: By performing the criteria weight vector ($W = [W_h]_H$) obtained from the SITDE method, a criterionbased weighted decision matrix ($G = [G_{dh}]_{DH}$) is constructed, as shown in Eq. (7), thereby incorporating the relative importance of the criteria into the analysis:

$$G_{dh} = W_h\,(M_{dh} + 1)\,; \quad (d = 1, 2, \ldots, D;\ h = 1, 2, \ldots, H) \tag{7}$$

Step 3: In the third step of the MABAC method, the criterion-based Boundary Proximation Area (BPA) ($Z = [Z_h]_H$) is calculated, as shown in Eq. (8), which serves as a critical reference point for the subsequent ranking of alternatives:

$$Z_h = \left(\prod_{d=1}^{D} G_{dh} \right)^{1/D}; \quad (d = 1, 2, \ldots, D;\ h = 1, 2, \ldots, H) \tag{8}$$

Step 4: The distances ($A = [A_{dh}]_{DH}$) of the alternatives from the BPA are calculated as follows (Eq. (9)):

$$A_{dh} = G_{dh} - Z_h; \quad (d = 1, 2, \ldots, D;\ h = 1, 2, \ldots, H) \tag{9}$$

Step 5: In the fifth step, the total distance vector ($B = [B_d]_D$) is obtained by aggregating the distances of each alternative from the BPA. This vector is calculated on an alternative basis as follows (Eq. (10)):

$$B_d = \sum_{h=1}^{H} A_{dh}; \quad (d = 1, 2, \ldots, D;\ h = 1, 2, \ldots, H) \tag{10}$$

Step 6: In the final step of the MABAC method, a min distance-based normalization procedure is employed to enhance the interpretability of the countries' logistics performance values. The normalized performance scores $(R = [R_d]_D)$ are then computed for each country, enabling their ranking (Eq. (11)):

$$R_d = \frac{B_d - \min_d(B_d)}{\max_d(B_d) - \min_d(B_d)}; \quad (d = 1, 2, \ldots, D) \tag{11}$$

where, R_d represents the logistics performance of the d-th country. The performance ranking vector is defined as $R = (R_1, R_2, \ldots, R_D)$, subject to the normalization condition: $\sum_{d=1}^{D} R_d = 1$ and $R_d \geq 0\ \forall h$. Figure 1 illustrates the procedural steps and methodological flow of the SITDE–MABAC approach.

4 Case Study: Application of the SITDE–MABAC Method to E7 Countries

The E7 countries are classified as emerging economies, and their performance in logistics activities (which support and facilitate economic operations) is of critical importance. To enhance their economic development levels, E7 countries invest significant efforts in improving their logistics infrastructure and developing logistics-related activities. The aim of this case study is to determine and compare the logistics performance levels of those countries. Within this context, the proposed SITDE–MABAC method was employed to weight the logistics performance criteria and to assess the logistics performance levels of the E7 countries. For the implementation of the SITDE–MABAC method, the initial decision matrix must first be constructed. Accordingly, the logistics performance criteria reported in the World Bank publications were adopted as the evaluation criteria. The performance values of the countries with respect to these criteria were obtained from the World Bank database. Thus, the initial decision matrix was formed, and the necessary preparation for the application of the SITDE–MABAC method was completed.

According to the World Bank [28] LPI framework, six logistics performance criteria have been defined: customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness. These criteria reflect countries' levels of preparedness for logistics activities as well as their overall logistics performance. The logistics performance evaluation criteria adopted in this study are presented as follows:

- **Customs (x_1)**: This criterion captures the effectiveness and performance of customs administration, which plays a pivotal role in national logistics systems by directly influencing the efficiency, reliability, and continuity of logistics activities.
- **Infrastructure (x_2)**: This criterion reflects the level of development and performance of trade- and transport-related infrastructure, including all transportation modes and information technology systems.
- **International shipments (x_3)**: This criterion evaluates the extent to which transportation costs are managed efficiently, thereby influencing the overall competitiveness of a country's logistics system.
- **Logistics competence (x_4)**: This criterion assesses the extent to which logistics activities are coordinated and efficiently managed, thereby influencing the overall performance of the logistics system.
- **Tracking and tracing (x_5)**: This criterion assesses the extent to which logistics activities can be effectively tracked and traced, thereby enhancing transparency and reliability across the logistics system.
- **Timeliness (x_6)**: This criterion assesses the extent to which logistics activities meet scheduled delivery requirements, highlighting performance in terms of timeliness, reliability, and responsiveness.

Table 2 illustrates the performance of the E7 countries according to the logistics performance criteria and constitutes the initial decision matrix used in the SITDE–MABAC method. Thereafter, the procedural steps of the SITDE–MABAC method were systematically implemented to derive the logistics performance criteria weights and to obtain the logistics performance rankings of the E7 countries.

Table 2. Logistics performance scores of E7 countries across the LPI criteria

O_{dh}	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)
Brazil (L_1)	2.90	3.20	2.90	3.30	3.20	3.50
China (L_2)	3.30	4.00	3.60	3.80	3.80	3.70
India (L_3)	3.00	3.20	3.50	3.50	3.40	3.60
Indonesia (L_4)	2.80	2.90	3.00	2.90	3.00	3.30
Mexico (L_5)	2.50	2.80	2.80	3.00	3.10	3.50
Russia (L_6)	2.40	2.70	2.30	2.60	2.50	2.90
Türkiye (L_7)	3.00	3.40	3.40	3.50	3.50	3.60

Stage 1 of application: Weight vector estimation of logistics performance criteria using SITDE

Step 1: To determine the logistics performance levels of the E7 countries using the SITDE–MABAC method, the initial decision matrix $(O = [O_{dh}]_{DH})$ is constructed based on World Bank [28] data and is presented in Table 2.

An examination of the initial matrix reveals that China achieves the highest scores across the customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness criteria, whereas Russia records the lowest scores for these criteria.

Step 2: Eq. (2) is applied to transform the initial decision matrix into a normalized form, and the resulting normalized matrix ($N = [N_{dh}]_{DH}$) is presented in Table 3 for subsequent analysis.

Table 3. Normalized matrix ($N = [N_{dh}]_{DH}$) for SITDE

N_{dh}	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)
Brazil (L_1)	0.8276	0.8438	0.7931	0.7879	0.7813	0.8286
China (L_2)	0.7273	0.6750	0.6389	0.6842	0.6579	0.7838
India (L_3)	0.8000	0.8438	0.6571	0.7429	0.7353	0.8056
Indonesia (L_4)	0.8571	0.9310	0.7667	0.8966	0.8333	0.8788
Mexico (L_5)	0.9600	0.9643	0.8214	0.8667	0.8065	0.8286
Russia (L_6)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Türkiye (L_7)	0.8000	0.7941	0.6765	0.7429	0.7143	0.8056

Step 3: Eq. (3) facilitates the calculation of the skewness values associated with each criterion, which are subsequently used to inform the construction of the weight vector criteria. The resulting skewness values ($S = [S_h]_H$) are presented in Table 4.

Step 4: Using Eq. (4), the logarithmic values ($L = [L_h]_H$) of each criterion are calculated to support the construction of the criteria weight vector and the normalization process. These values are provided in Table 4.

Step 5: Using Eq. (5), the final weights of the logistics performance criteria ($W = [W_h]_H$) are determined and applied to construct the weighted decision matrix for the SITDE–MABAC ranking procedure. These weights are provided in Table 4.

Table 4. Skewness values ($S = [S_h]_H$), logarithmic values ($L = [L_h]_H$) and final criteria weights ($W = [W_h]_H$)

	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)
S_h	0.5498	-0.5754	1.0939	0.6263	1.1399	1.8591
L_h	0.4949	0.3010	0.5646	0.5054	0.5700	0.6468
W_h	0.1605	0.0977	0.1831	0.1639	0.1849	0.2098
Rank	5th	6th	3rd	4th	2nd	1st

Stage 2 of application: Performance rank vector estimation of E7 countries using MABAC

Step 1: Once the criteria weight vector has been established, the initial decision matrix is normalized using a max-min distance-based procedure in Eq. (6) to enable the application of the MABAC method for ranking the logistics performance of the E7 countries. The resulting normalized matrix ($M = [M_{dh}]_{DH}$) is provided in Table 5.

Table 5. Normalized matrix ($M = [M_{dh}]_{DH}$) for MABAC

M_{dh}	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)
Brazil (L_1)	0.5556	0.3846	0.4615	0.5833	0.5385	0.7500
China (L_2)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
India (L_3)	0.6667	0.3846	0.9231	0.7500	0.6923	0.8750
Indonesia (L_4)	0.4444	0.1538	0.5385	0.2500	0.3846	0.5000
Mexico (L_5)	0.1111	0.0769	0.3846	0.3333	0.4615	0.7500
Russia (L_6)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Türkiye (L_7)	0.6667	0.5385	0.8462	0.7500	0.7692	0.8750

Step 2: The weighted decision matrix ($G = [G_{dh}]_{DH}$), reflecting the relative importance of each criterion as defined by the weight vector criteria (Table 4), is constructed using Eq. (7) and is presented in Table 6.

Step 3: For each criterion, the BPA ($Z = [Z_h]_H$) is computed using Eq. (8) to facilitate the ranking process, and the results are presented in Table 6.

Step 4: The distances of all alternatives from the BPA ($A = [A_{dh}]_{DH}$) are determined using Eq. (9) to facilitate the ranking process, with the corresponding values presented in Table 7.

Step 5: For all alternatives, the distances from the BPA are summed up to compute the total distance vector ($B = [B_d]_D$), as shown in Eq. (10), with the results presented in Table 7.

Step 6: The final logistics performance values ($R = [R_d]_D$) for the E 7 countries are computed using Eq. (11), and the outcomes are summarized in Table 8.

The application of the SITDE–MABAC method indicates that, among the E7 countries, China achieves the highest logistics performance score, while Russia records the lowest score.

Table 6. Weighted matrix ($G = [G_{dh}]_{DH}$) and BPA ($Z = [Z_h]_H$)

G_{dh}	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)
Brazil (L_1)	0.2497	0.1352	0.2677	0.2596	0.2845	0.3672
China (L_2)	0.3211	0.1953	0.3663	0.3279	0.3698	0.4197
India (L_3)	0.2676	0.1352	0.3522	0.2869	0.3129	0.3934
Indonesia (L_4)	0.2319	0.1127	0.2818	0.2049	0.2560	0.3147
Mexico (L_5)	0.1784	0.1052	0.2536	0.2186	0.2702	0.3672
Russia (L_6)	0.1605	0.0977	0.1831	0.1639	0.1849	0.2098
Türkiye (L_7)	0.2676	0.1502	0.3381	0.2869	0.3271	0.3934
Z_h	0.2337	0.1298	0.2850	0.2440	0.2808	0.3447

Table 7. Distance matrix ($A = [A_{dh}]_{DH}$) and the total distance vector ($B = [B_d]_D$)

A_{dh}	Customs (x_1)	Infrastructure (x_2)	International Shipments (x_3)	Logistics Competence (x_4)	Customs (x_1)	Infrastructure (x_2)	B_d
Brazil (L_1)	0.0160	0.0054	-0.0173	0.0156	0.0036	0.0225	0.0458
China (L_2)	0.0873	0.0655	0.0813	0.0839	0.0890	0.0749	0.4819
India (L_3)	0.0338	0.0054	0.0672	0.0429	0.0321	0.0487	0.2301
Indonesia (L_4)	-0.0019	-0.0171	-0.0033	-0.0390	-0.0248	-0.0300	-0.1161
Mexico (L_5)	-0.0554	-0.0246	-0.0314	-0.0254	-0.0106	0.0225	-0.1249
Russia (L_6)	-0.0732	-0.0321	-0.1019	-0.0800	-0.0959	-0.1349	-0.5181
Türkiye (L_7)	0.0338	0.0204	0.0531	0.0429	0.0463	0.0487	0.2453

Table 8. Final logistics performance scores ($R = [R_d]_D$) of the E7 countries

	Brazil (L_1)	China (L_2)	India (L_3)	Indonesia (L_4)	Mexico (L_5)	Russia (L_6)	Türkiye (L_7)
W_h	0.5638	1.0000	0.7482	0.4020	0.3931	0.0000	0.7634
Rank	4th	1st	3rd	5th	6th	7th	2nd

5 Robustness Check

5.1 Sensitivity Check

A sensitivity analysis was conducted to test the robustness of the logistics performance results of the E7 countries obtained using the SITDE–MABAC method. The sensitivity check was performed by sequentially removing the countries with the lowest logistics performance from the decision model. At each stage, the country with the lowest performance was excluded from the model. According to the results, Russia, with the lowest logistics performance, was removed first. In the subsequent stage, Indonesia, which ranked last, was excluded. Mexico was removed in the following stage, followed by Brazil in the next stage. Across all sensitivity scenarios, China consistently remained the highest-ranking country. However, in the scenario where Russia was removed, Indonesia occupied the last position instead of Mexico. Additionally, when Brazil was excluded, Türkiye ranked last in place of India. The performance results under the sensitivity analysis are illustrated in Figure 2, while the corresponding rankings of the E7 countries for the same scenarios are presented in Figure 3.

5.2 Comparative Check

The MABAC method was employed to rank the logistics performance of the E7 countries. To support the robustness of the results, several alternative ranking methods were also applied for comparison. Specifically, the ALWAS, Additive Ratio Assessment (ARAS), MARCOS, SAW, TOPSIS, and WASPAS methods were used, and their results were compared with those obtained from MABAC. The logistics performance scores of the E7 countries are illustrated in Figure 4, and the resulting rankings are presented in Table 9. Across all methods, the rankings were consistent, and the logistics performance values were closely aligned. A near-perfect correlation was observed among the results, confirming the robustness and reliability of the MABAC-based findings.

Figure 2. Logistics performance of the E7 countries according to sensitivity check

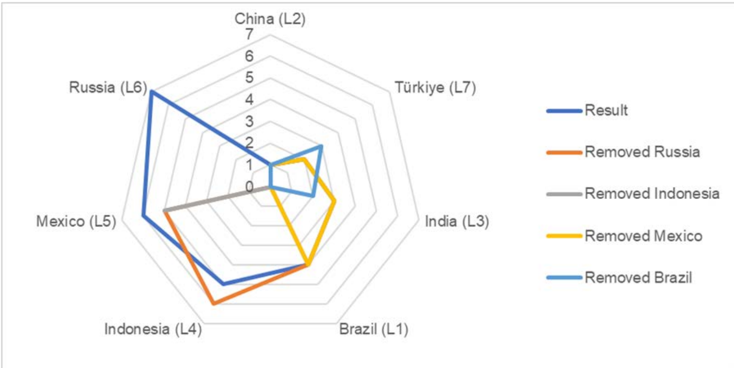

Figure 3. Logistics performance ranks of the E7 countries according to sensitivity check

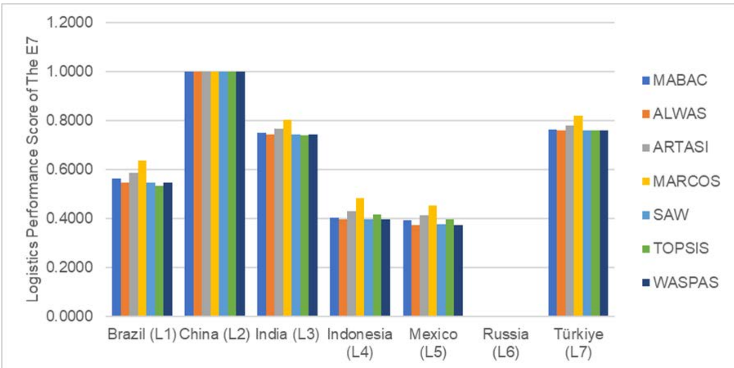

Figure 4. Logistics performance of the E7 countries according to comparative check

Table 9. Logistics performance ranks of the E7 countries according to comparative check

Methods	Rank	Best Performance	Worst Performance
MABAC	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
ALWAS	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
ARTASI	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
MARCOS	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
SAW	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
TOPSIS	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia
WASPAS	$L_2 > L_7 > L_3 > L_1 > L_4 > L_5 > L_6$	China	Russia

6 Results

The analysis of logistics performance for the E7 countries using the SITDE–MABAC method indicates that China achieves the highest logistics performance, followed by Türkiye, while Russia records the lowest performance. Among the six LPI criteria, timeliness was identified as the most critical factor influencing logistics performance, highlighting the importance of on-time delivery and schedule adherence in emerging economies. The robustness of these results was further confirmed through sensitivity and comparison analyses, which validated the consistency and reliability of the rankings. These findings are largely consistent with previous literature on logistics performance in other regional and global contexts. For example, Isik et al. [15] and Mešić et al. [18] also identified timeliness as a key determinant of logistics efficiency in Central and Eastern Europe and the Western Balkans, respectively. Similarly, studies [17, 24] on OECD and G20 countries emphasized infrastructure and customs as critical criteria; however, in the context of emerging economies, timely shipment delivery emerges as the most decisive factor, reflecting the dynamic trade environments and logistical challenges in these nations.

The superior performance of China aligns with its well-developed logistics infrastructure, streamlined customs procedures, and efficient supply chain operations, which are consistent with findings from prior research on global logistics leaders, such as Germany, Singapore, and Finland [5, 21]. A notable and distinctive finding in this study is the high logistics performance of Türkiye relative to other E7 countries, despite its comparatively lower level of economic development. This underscores the role of strategic investments and operational efficiencies in logistics systems, suggesting that emerging economies can achieve competitive logistics performance through targeted improvements in timeliness and supply chain management. The robustness of the SITDE–MABAC methodology was confirmed through sensitivity analysis, where China consistently retained the top position across all scenarios, and through comparison checks using alternative MCDM methods, including ALWAS, ARAS, MARCOS, SAW, TOPSIS, and WASPAS. Across all methods, the rankings were largely consistent, and near-perfect correlations were observed, further supporting the reliability of the results.

Overall, the study demonstrates that timeliness is the primary determinant of logistics performance among the E7 countries, and strategic interventions in this area can substantially enhance a country's competitiveness. The results not only align with the broader literature on logistics performance but also provide unique insights into emerging economies, highlighting actionable opportunities for policymakers and logistics managers to improve operational efficiency and global trade competitiveness.

7 Implications

7.1 Methodological Implications

The application of the SITDE–MABAC method in this study demonstrates a robust and systematic approach for evaluating logistics performance across multiple criteria. By integrating objective criteria through the SITDE method with the alternative ranking capability of MABAC, this methodology ensures an unbiased, data-driven evaluation process while accommodating the complexity of logistics systems. The robustness and reliability of the results, confirmed through sensitivity and comparison analyses, highlight the suitability of the SITDE–MABAC framework for emerging economies. This study contributes methodologically by offering a replicable framework for researchers and practitioners seeking to evaluate and compare logistics performance in other country groups or regional clusters.

7.2 Managerial Implications

For logistics managers and supply chain professionals in the E7 countries, the findings provide actionable insights into the most critical areas for performance improvement. Timeliness emerged as the most significant criterion influencing overall logistics performance, emphasizing the importance of efficient delivery systems, effective scheduling, and proactive management of delays. The results also indicate that strategic investments in logistics infrastructure and operational optimization can substantially enhance competitiveness, as evidenced by Türkiye's high ranking despite its relatively lower economic development level. Managers can leverage these insights to prioritize resource allocation, optimize operational processes, and benchmark performance against regional and global peers.

7.3 Policy Implications

From a policy perspective, the study underscores the importance of targeted national strategies to enhance logistics efficiency in emerging economies. Governments can focus on reducing bottlenecks in customs and border procedures, improving transport infrastructure, and strengthening tracking and tracing capabilities. The identification of timeliness as a key determinant suggests that regulatory and policy interventions should emphasize predictable, reliable, and fast delivery systems, particularly in facilitating international trade. Additionally, the comparative analysis of E7 countries can inform cross-country learning, enabling policymakers to adopt best practices from higher-performing nations such as China and Türkiye.

7.4 Implications for E7 Logistics Performance

The study provides a comprehensive assessment of logistics performance across the E7 countries, revealing significant differences in operational efficiency and competitiveness. China's leading position reflects the benefits of advanced infrastructure and streamlined supply chain practices, while Russia's lower ranking indicates areas requiring policy and operational improvements. The high performance of Türkiye highlights that emerging economies can achieve competitive logistics capabilities through targeted improvements and efficient resource utilization. These insights are crucial for shaping both short-term operational strategies and long-term national logistics policies, ultimately supporting sustainable economic growth and enhanced integration into global trade networks.

8 Conclusion

This study aimed to evaluate and compare the logistics performance of the E7 countries using the SITDE–MABAC method, a robust MCDM approach. The SITDE method was employed to objectively determine the weights of logistics performance criteria based on their skewness, while the MABAC method ranked the countries by calculating distances from criterion-based BPAs. The empirical analysis highlighted China as the top-performing country in terms of logistics, while Russia recorded the lowest performance. A notable finding is that Turkey, despite having a relatively lower level of economic development among the E7 nations, achieved the second-highest logistics performance, illustrating that effective logistics management and strategic investments can enhance a country's competitive position. The robustness and reliability of the SITDE–MABAC method were confirmed through sensitivity and comparison analyses. Sensitivity checks demonstrated that China consistently retained the top position across all scenarios, while comparison analyses using alternative MCDM methods produced consistent rankings with near-perfect correlations. These results validate the methodological strength of the SITDE–MABAC framework, demonstrating its suitability for comprehensive logistics performance evaluation in emerging economies.

The findings of this study have both theoretical and practical implications. The research contributes methodologically by providing a replicable approach for assessing logistics performance across multiple criteria. Practically, it offers actionable insights for policymakers and logistics managers in E7 countries, emphasizing the importance of timeliness, infrastructure development, and efficient supply chain management. By highlighting strengths and weaknesses in the logistics systems of these emerging economies, the study supports informed decision-making aimed at improving logistics efficiency, enhancing competitiveness, and fostering sustainable economic growth.

8.1 Limitations and Future Suggestions

This study has several limitations and offers directions for future research. First, the analysis focuses solely on the E7 countries, which limits the generalizability of the findings to other economies. Future research could expand the scope to include additional country groups or global comparisons to validate and extend the results. Second, the study relies on the LPI data provided by the World Bank, which, while comprehensive, may not capture all qualitative aspects of logistics performance, such as managerial practices or private sector innovations. Incorporating alternative data sources or more granular logistics performance indicators could provide a more nuanced understanding of country-level logistics efficiency. Third, although the SITDE–MABAC method has demonstrated robustness through sensitivity and comparison analyses, the study focuses on a single MCDM framework. Future research could explore hybrid or dynamic MCDM approaches, combining subjective expert assessments with objective weighting methods, to further enhance decision-making accuracy. Additionally, the current analysis considers static logistics performance, whereas logistics systems are dynamic and influenced by evolving policies, infrastructure projects, and global trade trends. Longitudinal studies capturing temporal changes in logistics performance could provide insights into the effectiveness of policy interventions and investments over time.

Finally, this study highlights the importance of specific criteria such as timeliness, customs efficiency, and infrastructure. Future research could investigate the underlying factors driving these critical performance indicators, including technological adoption, regulatory frameworks, and international trade agreements. Comparative studies across emerging and developed economies could also uncover best practices that support logistics competitiveness, offering actionable recommendations for policymakers, supply chain managers, and international trade organizations. By addressing these limitations, future studies can contribute to a more comprehensive understanding of global logistics performance and its impact on economic growth and competitiveness.

Author Contributions

Conceptualization, K.K., G.C.Y., and E.K.Ö.; methodology, K.K., G.C.Y., and E.K.Ö.; software, K.K., G.C.Y., and E.K.Ö.; validation, K.K., G.C.Y., and E.K.Ö.; formal analysis, K.K., G.C.Y., and E.K.Ö.; investigation, K.K., G.C.Y., and E.K.Ö.; resources, K.K., G.C.Y., and E.K.Ö.; data curation, K.K., G.C.Y., and E.K.Ö.; writing—original draft preparation, K.K., G.C.Y., and E.K.Ö.; writing—review and editing, K.K., G.C.Y., and E.K.Ö.; visualization, K.K., G.C.Y., and E.K.Ö.; supervision, K.K., G.C.Y., and E.K.Ö.; project administration, K.K., G.C.Y., and E.K.Ö.; funding acquisition, K.K., G.C.Y., and E.K.Ö. All authors have read and agreed to the published version of the manuscript.

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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Appendix

Indices and Sets	
$d = 1, 2, \ldots, D$	Index of countries
$h = 1, 2, \ldots, H$	Index of logistics performance evaluation criteria
$L = \{L_1,\ L_2, \ldots,\ L_d, \ldots,\ L_D\}$	Set of countries
$x = \{x_1, x_2, \ldots, x_h, \ldots, x_H\}$	Set of logistics performance evaluation criteria
$x^- \subseteq x$	Set of cost-based logistics performance evaluation criteria
$x^+ \subseteq x$	Set of benefit-based logistics performance evaluation criteria

Parameters	
$D \geq 2$	Number of countries
$H \geq 2$	Number of logistics performance evaluation criteria

Variables	
$O_{dh}(d \in\ L,\ h \in x)$	Initial score of the country L_d according to logistics performance evaluation criterion x_h
$N_{dh}(d \in\ L,\ h \in x)$	Normalized value of the country L_d according to logistics performance evaluation criterion x_h
$S_h(h \in x)$	Skewness value of the logistics performance evaluation criterion x_h
$L_h(h \in x)$	Logarithmic value of the logistics performance evaluation criterion x_h
$W_h(h \in x)$	Weight of the logistics performance evaluation criterion x_h
$M_{dh}(d \in\ L,\ h \in x)$	Normalized value of the country L_d according to logistics performance evaluation criterion x_h
$G_{dh}(d \in\ L,\ h \in x)$	Weighted value of the country L_d according to logistics performance evaluation criterion x_h
$Z_h(h \in x)$	BPA value of the logistics performance evaluation criterion x_h
$A_{dh}(d \in\ L,\ h \in x)$	Distance value of the country L_d according to logistics performance evaluation criterion x_h
$B_d(h \in x)$	Total distance value of the country L_d
$R_d(h \in x)$	Logistics performance value of the country L_d