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A HYBRID SPC-MARA DECISION MODEL FOR ASSESSING THE SUPPLY CHAIN PERFORMANCE OF EUROPEAN COUNTRIES

Emre Kadir ÖZEKENCİ*

Abstract

This paper analyzes the supply chain performance of various European countries through a hybrid Multi-Criteria Decision-Making (MCDM) model. The evaluation of supply chain performance is based on ten criteria identified through a literature review. Data for this study were obtained from the World Bank's report. The criteria weights are determined using the Symmetry Point of Criterion (SPC) method, while evaluating supply chain performance across European countries is conducted by the Magnitude of the Area for the Ranking of Alternatives (MARA) method. The SPC analysis indicates that maritime connectivity is the most critical criterion, whereas postal connectivity is deemed the least significant. The MARA findings highlight that the Netherlands, the United Kingdom, Germany, Spain, and Cyprus exhibit the highest supply chain performance levels. Conversely, Denmark, Slovenia, Lithuania, Bulgaria, and Malta show the lowest performance. Additionally, a comparative analysis was performed to validate the robustness of the results.

Keywords: *Supply chain, European countries, MCDM, SPC, MARA.*

JEL Classification Codes: *C60, L91, R40*

AVRUPA ÜLKELERİNİN TEDARİK ZİNCİRİ PERFORMANSINI DEĞERLENDİRMEK İÇİN HİBRİT SPC-MARA KARAR MODELİ

Öz

Bu makalede çeşitli Avrupa ülkelerinin tedarik zinciri performansı hibrit Çok Kriterli Karar Verme (ÇKKV) modeliyle analiz edilmektedir. Tedarik zinciri performansının değerlendirilmesi, literatür taramasıyla belirlenen on kritere dayanmaktadır. Bu çalışmanın verileri Dünya Bankası raporundan elde edilmiştir. Kriter ağırlıkları, Kriter Simetri Noktası (SPC) yöntemi kullanılarak belirlenirken, Avrupa ülkeleri genelindeki tedarik zinciri performansının değerlendirilmesi Alternatiflerin Sıralanması Alan Büyüklüğü (MARA) yöntemi ile gerçekleştirilmiştir. SPC analizi, deniz bağlantısının en kritik kriter olduğunu, posta bağlantısının ise en az önemli kriter olarak kabul edildiğini göstermektedir. MARA bulguları, Hollanda, Birleşik Krallık, Almanya, İspanya ve Kıbrıs'ın en yüksek tedarik zinciri performans seviyelerini sergilediğini vurgulamaktadır. Tersine, Danimarka, Slovenya, Litvanya, Bulgaristan ve Malta en düşük performansı göstermektedir. Ek olarak, sonuçların tutarlılığını doğrulamak için karşılaştırmalı analiz yapılmıştır.

Anahtar kelimeler: *Tedarik zinciri, Avrupa ülkeleri, ÇKKV, SPC, MARA.*

JEL Kodları: *C60, L91, R40*

*Assoc. Prof., Cag University, International Trade and Logistics Department, MERSİN.
e-mail: ekadirozekenci@cag.edu.tr, (https://orcid.org/0000-0001-6669-0006)

1. INTRODUCTION

A supply chain can be described as a network of various business entities that collaboratively contribute to creating value associated with a product or service. These entities are interconnected by moving goods, information, and funds. In its ideal form, the supply chain encompasses all business processes across multiple organizations, from the initial supplier to the final point of consumption (Sutia et al., 2020). Supply chain management (SCM) generates value for organizations, customers, and stakeholders engaged in the supply chain. Given the strategic significance of supply chains, it is essential to measure their performance rigorously. Supply chain performance can be assessed based on customer satisfaction—which ultimately reflects the value created at the logistics level—and the costs incurred. Evaluating supply chain performance is a complex task, partly because it involves multiple stakeholders working together to achieve specific logistical and strategic objectives. Such evaluations are especially crucial when supply chains are regarded as crucial to corporate success (Estampe et al., 2013). An important aspect of effective supply chain management is measuring and monitoring outcomes related to critical operational and performance parameters, including delivery schedules and lead times (Gunasekaran & Ngai, 2004).

In today's world, supply chains represent intricate business networks that require collaborative management and global optimization. The global business landscape is continually and rapidly evolving. Traits such as uncertainty, increased competition, shorter cycle times, more demanding customers, and pressure to reduce costs characterize the 21st-century business environment. Consequently, it has become essential to measure, monitor, and manage the performance of supply chain processes. Performance management involves applying processes, methods, metrics, and technologies to establish a cohesive relationship between supply chain strategy, planning, implementation, and control. In the past decade, SCM has received significant attention from academic and industry circles. However, a notable gap persists in integrating SCM and performance measurement. Most performance measurement models and frameworks focus on single organizations or particular performance categories, such as financial metrics. Nevertheless, performance measurement is vital for the effective management of supply chains. Timely and accurate evaluation of the entire supply chain is crucial for its successful operation (Stefanovic, 2014).

Over the last few decades, global supply chains have experienced significant disruptions due to various events, including the financial crisis of 2008, the United Kingdom's decision to exit the European Union (commonly referred to as Brexit) in 2016, the recent global pandemic caused by COVID-19, and the conflict between Russia and Ukraine (Hashmi, 2022; Allam et al., 2022). Consequently, significant research has been dedicated to exploring the various aspects of supply chain performance using the MCDM approach. Chithambaranathan et al. (2015) evaluated the environmental performance of service supply chains using gray-based ELECTRE and VIKOR methods. Uygun and Dede (2016) analyzed green supply chain performance through Fuzzy DEMATEL, fuzzy ANP, and TOPSIS techniques. Sufiyan et al. (2019) investigated food supply chain performance using fuzzy DEMATEL and DANP methods. Chand et al. (2020) assessed supply chain performance metrics for Indian manufacturing companies using the DELPHI technique, the Best-Worst Method (BWM), and DEMATEL. Wang et al. (2022) examined agricultural supply chain performance in Vietnam through a hybrid approach that combines SF-AHP and CODAS methods. Oubrahim and Sefiani (2024) explored sustainable supply chain performance in the manufacturing sector utilizing BWM and DEMATEL methods. Kara et al. (2024) analyzed supply chain performance across 72 countries using MPSI-ARLON methods.

From the existing literature, there is a limited body of research focused on measuring the supply chain performance of countries by employing macro data through MCDM methods. Parallel to this, the current study analyzes the supply chain performance of European countries using hybrid MCDM methods. Evaluating supply chain performance is essential for European countries as it boosts economic competitiveness, advances sustainability objectives, and enhances resilience against disruptions. Additionally, supply chain assessments contribute to reducing carbon footprints, fulfilling customer expectations for dependable service, and adhering to intricate regulatory frameworks. Overall, this study seeks to explore the following research questions:

RQ1. *What are the key factors that influence the supply chain performance of European countries?*

RQ2. *How do European countries compare in terms of their supply chain performance?*

RQ3. *Does the supply chain performance of European countries differ depending on the MCDM methods applied?*

A new model is applied that integrates a novel weighting approach (SPC) with a new ranking-based method (MARA). The rationale behind selecting this hybrid model can be summarized as follows: The first advantage of the SPC method is its provision of a novel, objective weighting technique for determining the significance of criteria. Every MCDM approach should strive to enhance objectivity throughout the decision-making process. Given the crucial role that attribute significance plays in decision-making, this proposed method assists decision-makers in achieving a more objective and reliable ranking of alternatives. The second advantage of the SPC method is its capacity to evaluate the performance of mineral deposit partitioning algorithms efficiently. This approach introduces an innovative mechanism for assessing the effectiveness of each partitioning algorithm. A uniform distribution of weighted coefficients indicates high efficiency within the algorithm. The SPC method is also flexible and comprehensible, easily integrating with traditional MCDM techniques to address many problems (Gligorić et al., 2023). The MARA method offers a practical and adaptable framework for addressing complex MCDM problems. Its applicability, flexibility in real-world scenarios, relatively short computation times, and inherent simplicity are among the numerous positive attributes recognized in the developed decision algorithm (Gligorić et al., 2022). The SPC-MARA hybrid model is employed to assess the supply chain performance of various European nations by utilizing macro-level data through an MCDM framework. The contributions of this research can be summarized as follows:

- A novel hybrid model is implemented as a comprehensive decision-support framework to assess European countries' supply chain performance.
- The SPC-MARA model is applied for the first time in the MCDM field to evaluate the supply chain performance of European countries.
- The developed hybrid method provides a decision support system that helps the private sector, policymakers, and other stakeholders analyze European countries' supply chain performance.
- The hybrid model is validated through comparative analysis.

The structure of this paper is organized as follows: Section 2 provides an overview of the data and research methodology, with a particular focus on the SPC and MARA methods. Section 3 presents the findings derived from the hybrid MCDM methods, including results from the comparative analysis. Finally, Section 4 summarizes the key findings and provides recommendations and implications for future research.

2. DATA AND METHODOLOGY

2.1. Data

This research analyzes the supply chain performance of European countries, including Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, and the United Kingdom. Supply chain performance analysis was conducted based on ten criteria: maritime connectivity, aviation connectivity, postal connectivity, mean turnaround time at port, mean aviation import dwell time, mean delivery time for postal activities, mean consolidated import dwell time, mean port import dwell time, mean consolidated export dwell time, and mean port export dwell time. The criteria were established based on a recent study by Kara et al. (2024). Data was obtained from the World Bank's (2023) reports (https://lpi.worldbank.org/report). The first three criteria are benefit-oriented because they aim to achieve maximum results, while the remaining criteria are non-benefit-oriented as they focus on achieving minimum results. The summary of the criteria is presented in Table 1. The decision matrix was also created using data gathered from the reports, as shown in Table 2.

Table 1. Overview of Criteria

Criteria (KPI)	Abbreviation	Optimization	Unit	Data Provider
Maritime connectivity	C_1	Benefit	Number of countries	MDS Trans modal Cargo IQ Universal Postal Union Trade Lens Marine Traffic
Aviation connectivity	C_2	Benefit	Number of countries	
Postal connectivity	C_3	Benefit	Number of countries	
Mean Turnaround time at the port	C_4	Cost	Days	
Mean aviation import dwell time	C_5	Cost	Days	
Mean delivery time for postal activities	C_6	Cost	Days	
Mean consolidated import dwell time	C_7	Cost	Days	
Mean port import dwell time	C_8	Cost	Days	
Mean consolidated export dwell time	C_9	Cost	Days	
Mean port export dwell time	C_{10}	Cost	Days	

Source: Arvis et al. (2023)

Table 2. Decision Matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Belgium	114.00	141.00	107.50	1.60	0.90	5.60	10.40	8.30	7.70	7.30
Bulgaria	6.00	83.50	107.00	1.30	1.30	8.00	8.60	8.60	8.40	8.00
Croatia	7.00	68.50	106.50	1.10	2.60	2.00	7.10	6.60	8.80	8.80
Cyprus	12.00	89.00	108.00	0.70	1.30	2.10	3.30	3.30	1.80	1.80
Denmark	17.00	123.00	138.00	0.80	1.80	4.70	8.40	6.90	8.10	8.10
Estonia	8.00	69.50	113.00	1.00	1.70	4.50	4.70	4.70	6.20	5.70
Finland	30.00	104.00	134.00	1.40	1.70	2.50	12.50	12.50	9.40	9.40
France	71.00	149.50	141.00	1.50	1.30	3.00	8.10	7.90	9.50	9.20
Germany	119.00	149.50	150.50	1.70	1.50	1.70	12.10	10.20	8.40	7.70
Greece	55.00	111.50	131.50	1.40	2.20	4.80	5.20	5.20	4.60	4.60
Italy	94.00	144.50	142.50	1.30	2.60	4.50	9.00	8.00	7.40	7.00
Latvia	9.00	64.50	108.50	1.40	2.10	1.80	8.00	8.00	9.30	9.30
Lithuania	16.00	75.50	119.00	0.80	2.40	5.60	8.50	8.40	9.20	9.10
Malta	22.00	66.00	105.00	1.30	2.00	5.10	25.00	25.00	8.20	8.20
Netherlands	137.00	145.00	148.50	1.30	0.80	1.50	9.40	7.20	6.50	5.60
Norway	30.00	108.00	139.50	0.50	1.60	4.90	5.00	4.80	6.90	6.90
Poland	29.00	104.00	136.50	1.40	2.50	3.00	11.20	10.30	8.10	7.40
Portugal	50.00	110.50	113.00	1.10	2.10	13.20	7.70	6.90	5.80	5.60
Romania	13.00	91.50	122.00	2.50	1.90	2.30	10.30	9.60	5.50	5.30
Slovenia	14.00	73.00	106.50	1.30	2.10	3.60	8.00	7.50	7.10	7.10
Spain	144.00	136.50	142.00	1.00	1.80	5.80	8.50	7.70	9.80	9.30
Sweden	30.00	116.50	137.00	1.00	2.00	2.80	7.60	6.60	7.70	7.40
United Kingdom	133.00	152.50	139.50	1.20	1.00	2.40	8.50	7.20	10.30	9.80

2.1.1. Definition of Criteria

This study evaluates the supply chain performance of European countries based on international tracking criteria, emphasizing two primary aspects: "connectivity" and "dwell time." Ten indicators from the World Bank's 2023 report are considered to measure the supply chain performance. The definitions of these criteria are provided below (Arvis et al., 2023; 2024):

(C_1)- Maritime Connectivity: This indicator measures a country's integration and effectiveness within global maritime networks. It indicates the efficiency and capacity of ports, shipping services, and logistics infrastructure in supporting trade flows. This evaluation considers factors such as the frequency and coverage of shipping routes, port handling times, and connectivity to major global trade hubs. Ultimately, it provides valuable insights into a nation's capability to facilitate seamless supply chain operations through maritime transport.

(C_2)- Aviation connectivity: This indicator measures a country's integration into global air transport networks. It assesses the efficiency, frequency, and reach of air cargo and passenger services that connect a nation to international markets. The evaluation considers the number of routes, flight frequencies, and connectivity to major air hubs. This analysis underscores a country's capacity to bolster global supply chain operations and enhance trade and economic activities through aviation.

(C_3)-Pos Emre Kadir ÖZEKENCİ tal connectivity: This indicator measures a country's postal system's efficiency and reliability in facilitating domestic and international deliveries. It considers aspects such as delivery times, network coverage, and the integration of postal services within global logistics and trade networks. This metric reflects the postal system's capability to support e-commerce, trade, and supply chain operations effectively.

(C_4)- Mean Turnaround time at port: This indicator measures the average duration a vessel remains at a port, from arrival to departure. It encompasses all activities, including unloading, loading, and essential port services. This metric reflects the efficiency of port operations, where shorter turnaround times signify more streamlined processes and enhanced support for global supply chain performance.

(C_5)- Mean aviation import dwell time: This indicator measures the average duration that imported goods remain in airport facilities, from arrival until they are cleared for onward transportation. It reflects the efficiency of airport customs, handling, and logistics processes. Shorter dwell times suggest faster throughput and indicate improved performance in supporting supply chain operations.

(C_6)- Mean delivery time for postal activities: This indicator measures the average time for postal items to be delivered from the sender to the recipient. It encompasses processing, handling, and transit times within domestic and international postal networks. Shorter delivery times reflect a more efficient and reliable postal system, which is vital for facilitating e-commerce and global supply chain operations.

(C_7)- Mean consolidated import dwell time: This indicator measures the average time imported goods spend in storage or transit facilities—such as ports, airports, or warehouses—before they are cleared for final delivery. It comprehensively evaluates a country's import efficiency by consolidating data across various transportation modes and logistics hubs. Shorter dwell times reflect more effective supply chain and customs operations.

(C_8)- Mean port import dwell time: This indicator measures the average duration that imported goods remain in port facilities, from when they are unloaded until they receive clearance for onward transport. It reflects the efficiency of port operations, customs processing, and logistics coordination. Shorter dwell times signify a more streamlined import process, contributing positively to overall supply chain performance.

(C_9)- Mean consolidated export dwell time: This indicator measures the average duration that export goods remain in logistics facilities—such as ports, airports, or warehouses—from when they arrive until they depart for international shipment. Consolidating data across various transport modes and logistics hubs provides a comprehensive assessment of the efficiency of export handling processes. Shorter dwell times reflect more efficient export logistics and enhanced supply chain performance.

(C_{10})- Mean port export dwell time: This indicator measures the average duration that export goods remain at port facilities, from their arrival at the port to their clearance for shipment. It reflects the efficiency of port operations, customs processing, and the overall logistics of exports. Shorter dwell times signify faster export handling, enhancing global supply chain efficiency.

2.2. Methodological framework

A hybrid SPC-MARA decision model comprises two stages and thirteen steps. In the first stage, the six steps of the SPC method are employed to weigh the criteria. In the second stage, the seven steps of the MARA method are applied to rank the alternatives. The definition of the hybrid model is outlined below.

2.2.1. SPC Method

The Symmetry Point of Criterion (SPC) method was introduced by Gligorić et al. in 2023 to assess the weights of criteria in various MCDM problems. This novel objective approach aims to determine the weight of each criterion effectively. The SPC method utilizes the symmetry point of a criterion, specifically the modulus of symmetry, to evaluate its influence on the overall weights. A higher modulus value signifies a greater weight assigned to the criterion. The following steps outline the process for estimating the weights of criteria (Gligorić et al., 2023):

Step 1. The decision matrix is created.

Step 2. According to Eq. (1), the Symmetry Point of Criterion (SPC_j) is calculated.

$$SPC_j = \frac{\min\{x_{ij}\} + \max\{x_{ij}\}}{2};\ \ i = 1,2,\ldots\ldots,m;\ \forall j\ \in [1,n] \tag{1}$$

Step 3. Applying Eq. (2) establishes the matrix of absolute distances.

$$D = \left\|d_{ij}\right\|_{mXn} = \begin{vmatrix} |x_{11} - SPC_1| & |x_{12} - SPC_2| & \ldots & |x_{1n} - SPC_n| \\ |x_{21} - SPC_1| & |x_{22} - SPC_2| & \ldots & |x_{2n} - SPC_n| \\ \vdots & \vdots & \ddots & \vdots \\ |x_{m1} - SPC_1| & |x_{m2} - SPC_2| & \ldots & |x_{mn} - SPC_n| \end{vmatrix} \tag{2}$$

Step 4. Based on Eq. (3), the matrix of the moduli of symmetry is created.

$$R = \left|r_{ij}\right|_{mXn} = \begin{vmatrix} \dfrac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{11}} & \dfrac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{12}} & \ldots & \dfrac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{1n}} \\ \dfrac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{21}} & \dfrac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{22}} & \ldots & \dfrac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \dfrac{\frac{\sum_{i=1}^{m} d_{i1}}{m}}{x_{m1}} & \dfrac{\frac{\sum_{i=1}^{m} d_{i2}}{m}}{x_{m2}} & \ldots & \dfrac{\frac{\sum_{i=1}^{m} d_{in}}{m}}{x_{mn}} \end{vmatrix} \tag{3}$$

Step 5. The modulus of symmetry of the criterion is established using Eq. (4).

$$Q = \left|q_{1j}\right|_{1Xn} = \left|\frac{\sum_{i=1}^{m} r_{i1}}{m} \quad \frac{\sum_{i=1}^{m} r_{i2}}{m} \quad \ldots \quad \frac{\sum_{i=1}^{m} r_{in}}{m}\right|;\ \forall j\ \in [1,n] \tag{4}$$

Step 6. Each objective criterion weight is calculated using the vector of moduli of symmetry (Eq. 5).

$$W = \left|w_{1j}\right|_{1Xn} = \left|\frac{q_1}{\sum_{j=1}^{n} q_j} \quad \frac{q_2}{\sum_{j=1}^{n} q_j} \quad \cdots \quad \frac{q_j}{\sum_{j=1}^{n} q_j}\right|;\ \forall j\ \in [1,n] \tag{5}$$

2.2.2. MARA Method

The Magnitude of the Area for the Ranking of Alternatives (MARA) method is introduced as a novel MCDM technique designed to establish the final rankings of alternatives. This method is fundamentally based on two key functions: one corresponding to the optimal alternative and the other to each alternative. A crucial aspect of this approach involves calculating the area under both the optimal alternative and each alternative, which is essential for determining the magnitude of the area. The area beneath each alternative is computed through the definite integration of a linear function from 0 to 1. The following steps outline the process of the MARA method (Gligorić et al., 2022):

Step 1. The decision matrix is normalized through Eq. (6-7).

$$r_{ij} = \frac{x_{ij}}{\underbrace{max}_{i=1,2,3....,m} x_{ij}} \tag{6}$$

$$r_{ij} = \frac{\underbrace{min}_{i==1,2,3....,m} \quad x_{ij}}{x_{ij}} \tag{7}$$

Step 2. According to Eq. (8), the weighted normalized decision matrix is created.

$$g_{ij} = w_j r_{ij,} \forall i \in \ [1, 2,3 \dots \dots, m], \qquad \forall j \in \ [1, 2,3 \dots \dots, n] \tag{8}$$

Step 3. The optimal alternative is determined by utilizing Eqs. (9-10).

$$S_j = \max(g_{ij} | 1 < j \leq n) \ \forall i \in \ [1, 2,3 \dots \dots, m] \tag{9}$$

$$S = \{s_1, s_2, \dots \dots .., s_j\} \quad j = 1,2, \dots \dots, n \tag{10}$$

Step 4. Decomposition of the optimal alternative is established using Eqs. (11-12).

$$S = S^{max} \ \cup S^{min} \tag{11}$$

$$S = \{s_1, s_2, \dots \dots .., s_k\} \ \cup \ \{s_1, s_2, \dots \dots .., s_l\} \, ; k + 1 = j \tag{12}$$

Step 5. The decomposition of each alternative is defined by Eqs. (13-14).

$$T_i = T_i^{max} \cup T_i^{min} \, , \forall i \in \ [1, 2,3 \dots \dots, m] \tag{13}$$

$$T_i = \{t_{i1}, t_{i2}, \dots \dots .., t_{ik}\} \ \cup \ \{t_{i1}, t_{i2}, \dots \dots .., t_{il}\}, \qquad \forall i \in \ [1, 2,3 \dots \dots, m] \tag{14}$$

Step 6. For the optimal alternative, the intensity of the element is computed based on Eqs. (15-18).

$$S_k = s_1 + s_2 + \cdots + s_k \tag{15}$$

$$S_l = s_1 + s_2 + \cdots + s_l \tag{16}$$

$$T_{ik} = t_{i1} + t_{i2}, \dots \dots + t_{ik} \ \forall i \in \ [1, 2,3 \dots \dots, m] \tag{17}$$

$$T_{il} = t_{i1} + t_{i2}, \dots \dots + t_{ik} \ \forall i \in \ [1, 2,3 \dots \dots, m] \tag{18}$$

Step 7. According to Eqs. (19-23), the final ranking of the alternatives is determined.

$$f^{opt}(S_k, S_l) = \frac{S_l - S_k}{1 - 0} \ (x - S_k) + S_k = (S_l - S_k)x + S_k \tag{19}$$

$$f^{i}(T_{ik}, T_{il}) = \frac{T_{il} - T_{ik}}{1 - 0} \ (x - T_{\mathrm{i}k}) + T_{\mathrm{i}k} = (T_{\mathrm{i}l} - t_{ik})x + T_{ik} \tag{20}$$

$$F^{opt} = \int_0^1 f^{opt}\,(S_k, S_l)dx = \int_0^1 \big((S_l - S_k)x + S_k\big)dx = \frac{S_l - S_k}{2} + S_k \tag{21}$$

$$F^{i} = \int_0^1 f^{i}\,(T_{ik}, T_{il})dx = \int_0^1 \big((T_{il} - T_{ik})x + T_{ik}\big)dx = \frac{T_{il} - T_{ik}}{2} + T_{ik};\ \forall i \in\ [1, 2,3 \dots \dots, m] \tag{22}$$

$$M_i = \int_0^1 f^{opt}(S_k, S_l)dx - \int_0^1 f^{i}(T_{ik}, T_{il})dx;\ \forall i \in\ [1, 2,3 \dots \dots, m] \tag{23}$$

Final ranking of the alternatives is determined according to the ascending order of M

3. RESULTS

3.1. The results obtained from the SPC Method

In the initial step of the SPC method, a decision matrix is established, incorporating the numerical values derived from the World Bank's report (2023), as depicted in Table 2. The second step involves computing the Symmetry Point of Criterion using the equations outlined in Eq. (1), as shown in Table 3. Then, the matrix of absolute distances is generated according to Eq. (2), illustrated in Table 4. Following this, the modulus of symmetry of the criterion is calculated based on Eq. (4) and presented in Table 5. Finally, the weight of the criteria is determined using Eq. (5), with the results of the SPC method displayed in Table 6.

Table 3. Symmetry Point of Criterion

Criterion	*Min min (x_{ij})*	*Max max (x_{ij})*	*Symmetry Point*
C_1	6	144	75
C_2	64.5	152.5	108.5
C_3	105	150.5	127.75
C_4	0.5	2.5	1.5
C_5	0.8	2.6	1.7
C_6	1.5	13.2	7.35
C_7	3.3	25	14.15
C_8	3.3	25	14.15
C_9	1.8	10.3	6.05
C_{10}	1.8	9.8	5.8

Table 4. The matrix of absolute distances

Economy	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Belgium	39.00	32.50	20.25	0.10	0.80	1.75	3.75	5.85	1.65	1.50
Bulgaria	69.00	25.00	20.75	0.20	0.40	0.65	5.55	5.55	2.35	2.20
Croatia	68.00	40.00	21.25	0.40	0.90	5.35	7.05	7.55	2.75	3.00
Cyprus	63.00	19.50	19.75	0.80	0.40	5.25	10.85	10.85	4.25	4.00
Denmark	58.00	14.50	10.25	0.70	0.10	2.65	5.75	7.25	2.05	2.30
Estonia	67.00	39.00	14.75	0.50	0.00	2.85	9.45	9.45	0.15	0.10
Finland	45.00	4.50	6.25	0.10	0.00	4.85	1.65	1.65	3.35	3.60
France	4.00	41.00	13.25	0.00	0.40	4.35	6.05	6.25	3.45	3.40
Germany	44.00	41.00	22.75	0.20	0.20	5.65	2.05	3.95	2.35	1.90

Greece	20.00	3.00	3.75	0.10	0.50	2.55	8.95	8.95	1.45	1.20
Italy	19.00	36.00	14.75	0.20	0.90	2.85	5.15	6.15	1.35	1.20
Latvia	66.00	44.00	19.25	0.10	0.40	5.55	6.15	6.15	3.25	3.50
Lithuania	59.00	33.00	8.75	0.70	0.70	1.75	5.65	5.75	3.15	3.30
Malta	53.00	42.50	22.75	0.20	0.30	2.25	10.85	10.85	2.15	2.40
Netherlands	62.00	36.50	20.75	0.20	0.90	5.85	4.75	6.95	0.45	0.20
Norway	45.00	0.50	11.75	1.00	0.10	2.45	9.15	9.35	0.85	1.10
Poland	46.00	4.50	8.75	0.10	0.80	4.35	2.95	3.85	2.05	1.60
Portugal	25.00	2.00	14.75	0.40	0.40	5.85	6.45	7.25	0.25	0.20
Romania	62.00	17.00	5.75	1.00	0.20	5.05	3.85	4.55	0.55	0.50
Slovenia	61.00	35.50	21.25	0.20	0.40	3.75	6.15	6.65	1.05	1.30
Spain	69.00	28.00	14.25	0.50	0.10	1.55	5.65	6.45	3.75	3.50
Sweden	45.00	8.00	9.25	0.50	0.30	4.55	6.55	7.55	1.65	1.60
United Kingdom	58.00	44.00	11.75	0.30	0.70	4.95	5.65	6.95	4.25	4.00

Table 5. The modulus of symmetry criterion

Economy	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Q	49.87	25.72	14.64	0.37	0.43	3.77	6.09	6.77	2.11	2.07
Belgium	0.4375	0.1824	0.1362	0.2310	0.4783	0.6727	0.5855	0.8159	0.2741	0.2835
Bulgaria	8.3116	0.3080	0.1368	0.2843	0.3311	0.4709	0.7080	0.7874	0.2513	0.2587
Croatia	7.1242	0.3754	0.1375	0.3360	0.1656	1.8837	0.8576	1.0260	0.2399	0.2352
Cyprus	4.1558	0.2890	0.1356	0.5280	0.3311	1.7940	1.8452	2.0520	1.1727	1.1498
Denmark	2.9335	0.2091	0.1061	0.4620	0.2391	0.8016	0.7249	0.9814	0.2606	0.2555
Estonia	6.2337	0.3700	0.1296	0.3696	0.2532	0.8372	1.2956	1.4408	0.3405	0.3631
Finland	1.6623	0.2473	0.1093	0.2640	0.2532	1.5070	0.4871	0.5417	0.2246	0.2202
France	0.7024	0.1720	0.1038	0.2464	0.3311	1.2558	0.7517	0.8572	0.2222	0.2250
Germany	0.4191	0.1720	0.0973	0.2174	0.2870	2.2161	0.5032	0.6639	0.2513	0.2688
Greece	0.9067	0.2306	0.1113	0.2640	0.1957	0.7849	1.1710	1.3023	0.4589	0.4499
Italy	0.5305	0.1780	0.1027	0.2843	0.1656	0.8372	0.6766	0.8465	0.2853	0.2957
Latvia	5.5411	0.3987	0.1349	0.2640	0.2050	2.0930	0.7611	0.8465	0.2270	0.2225
Lithuania	3.1168	0.3406	0.1230	0.4620	0.1793	0.6727	0.7164	0.8062	0.2294	0.2274
Malta	2.2668	0.3897	0.1394	0.2843	0.2152	0.7387	0.2436	0.2709	0.2574	0.2524
Netherlands	0.3640	0.1774	0.0986	0.2843	0.5380	2.5116	0.6478	0.9405	0.3247	0.3696
Norway	1.6623	0.2381	0.1050	0.7391	0.2690	0.7689	1.2178	1.4108	0.3059	0.2999
Poland	1.7196	0.2473	0.1073	0.2640	0.1722	1.2558	0.5437	0.6575	0.2606	0.2797
Portugal	0.9974	0.2327	0.1296	0.3360	0.2050	0.2854	0.7908	0.9814	0.3639	0.3696
Romania	3.8361	0.2811	0.1200	0.1478	0.2265	1.6380	0.5912	0.7054	0.3838	0.3905
Slovenia	3.5621	0.3523	0.1375	0.2843	0.2050	1.0465	0.7611	0.9029	0.2973	0.2915
Spain	0.3463	0.1884	0.1031	0.3696	0.2391	0.6496	0.7164	0.8794	0.2154	0.2225
Sweden	1.6623	0.2208	0.1069	0.3696	0.2152	1.3455	0.8012	1.0260	0.2741	0.2797
United Kingdom	0.3750	0.1686	0.1050	0.3080	0.4304	1.5697	0.7164	0.9405	0.2049	0.2112

Table 6. The weights of the criteria

Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
w_j	0.3601	0.0365	0.0166	0.0465	0.0375	0.1691	0.1108	0.1326	0.0448	0.0454
rank	1	9	10	5	8	2	4	3	7	6

The SPC results reveal that maritime connectivity (C_1) is the most significant criterion, while postal connectivity (C_3) ranks as the least important. Additionally, the mean delivery time for postal activities (C_6) and the mean port import dwell time (C_8) are critical indicators influencing the supply chain performance of European countries. The overall ranking of the criteria is as follows: $C_1 > C_6 > C_8 > C_7 > C_4 > C_{10} > C_9 > C_5 > C_2 > C_3$.

3.2. The results obtained from the MARA Method

The decision matrix was initially normalized by Eqs. (6-7). Subsequently, the weighted normalized decision matrix was derived utilizing Eq. (8). The normalized decision matrix and the weighted normalized decision matrix are provided in Tables 7 and 8, respectively.

Table 7. Normalized decision matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Belgium	0.7917	0.9246	0.7143	0.3125	0.8889	0.2679	0.3173	0.3976	0.2338	0.2466
Bulgaria	0.0417	0.5475	0.7110	0.3846	0.6154	0.1875	0.3837	0.3837	0.2143	0.2250
Croatia	0.0486	0.4492	0.7076	0.4545	0.3077	0.7500	0.4648	0.5000	0.2045	0.2045
Cyprus	0.0833	0.5836	0.7176	0.7143	0.6154	0.7143	1.0000	1.0000	1.0000	1.0000
Denmark	0.1181	0.8066	0.9169	0.6250	0.4444	0.3191	0.3929	0.4783	0.2222	0.2222
Estonia	0.0556	0.4557	0.7508	0.5000	0.4706	0.3333	0.7021	0.7021	0.2903	0.3158
Finland	0.2083	0.6820	0.8904	0.3571	0.4706	0.6000	0.2640	0.2640	0.1915	0.1915
France	0.4931	0.9803	0.9369	0.3333	0.6154	0.5000	0.4074	0.4177	0.1895	0.1957
Germany	0.8264	0.9803	1.0000	0.2941	0.5333	0.8824	0.2727	0.3235	0.2143	0.2338
Greece	0.3819	0.7311	0.8738	0.3571	0.3636	0.3125	0.6346	0.6346	0.3913	0.3913
Italy	0.6528	0.9475	0.9468	0.3846	0.3077	0.3333	0.3667	0.4125	0.2432	0.2571
Latvia	0.0625	0.4230	0.7209	0.3571	0.3810	0.8333	0.4125	0.4125	0.1935	0.1935
Lithuania	0.1111	0.4951	0.7907	0.6250	0.3333	0.2679	0.3882	0.3929	0.1957	0.1978
Malta	0.1528	0.4328	0.6977	0.3846	0.4000	0.2941	0.1320	0.1320	0.2195	0.2195
Netherlands	0.9514	0.9508	0.9867	0.3846	1.0000	1.0000	0.3511	0.4583	0.2769	0.3214
Norway	0.2083	0.7082	0.9269	1.0000	0.5000	0.3061	0.6600	0.6875	0.2609	0.2609
Poland	0.2014	0.6820	0.9070	0.3571	0.3200	0.5000	0.2946	0.3204	0.2222	0.2432
Portugal	0.3472	0.7246	0.7508	0.4545	0.3810	0.1136	0.4286	0.4783	0.3103	0.3214
Romania	0.0903	0.6000	0.8106	0.2000	0.4211	0.6522	0.3204	0.3438	0.3273	0.3396
Slovenia	0.0972	0.4787	0.7076	0.3846	0.3810	0.4167	0.4125	0.4400	0.2535	0.2535
Spain	1.0000	0.8951	0.9435	0.5000	0.4444	0.2586	0.3882	0.4286	0.1837	0.1935
Sweden	0.2083	0.7639	0.9103	0.5000	0.4000	0.5357	0.4342	0.5000	0.2338	0.2432
United Kingdom	0.9236	1.0000	0.9269	0.4167	0.8000	0.6250	0.3882	0.4583	0.1748	0.1837

Table 8. Weighted normalized decision matrix

Economy	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Belgium	0.2851	0.0338	0.0119	0.0145	0.0333	0.0453	0.0352	0.0527	0.0105	0.0112
Bulgaria	0.0150	0.0200	0.0118	0.0179	0.0231	0.0317	0.0425	0.0509	0.0096	0.0102
Croatia	0.0175	0.0164	0.0118	0.0211	0.0115	0.1268	0.0515	0.0663	0.0092	0.0093
Cyprus	0.0300	0.0213	0.0119	0.0332	0.0231	0.1208	0.1108	0.1326	0.0448	0.0454
Denmark	0.0425	0.0295	0.0152	0.0291	0.0167	0.0540	0.0435	0.0634	0.0100	0.0101
Estonia	0.0200	0.0166	0.0125	0.0232	0.0176	0.0564	0.0778	0.0931	0.0130	0.0143
Finland	0.0750	0.0249	0.0148	0.0166	0.0176	0.1014	0.0293	0.0350	0.0086	0.0087
France	0.1776	0.0358	0.0156	0.0155	0.0231	0.0845	0.0451	0.0554	0.0085	0.0089
Germany	0.2976	0.0358	0.0166	0.0137	0.0200	0.1492	0.0302	0.0429	0.0096	0.0106
Greece	0.1375	0.0267	0.0145	0.0166	0.0136	0.0528	0.0703	0.0842	0.0175	0.0178
Italy	0.2351	0.0346	0.0157	0.0179	0.0115	0.0564	0.0406	0.0547	0.0109	0.0117
Latvia	0.0225	0.0154	0.0120	0.0166	0.0143	0.1409	0.0457	0.0547	0.0087	0.0088
Lithuania	0.0400	0.0181	0.0131	0.0291	0.0125	0.0453	0.0430	0.0521	0.0088	0.0090
Malta	0.0550	0.0158	0.0116	0.0179	0.0150	0.0497	0.0146	0.0175	0.0098	0.0100
Netherlands	0.3426	0.0347	0.0164	0.0179	0.0375	0.1691	0.0389	0.0608	0.0124	0.0146
Norway	0.0750	0.0259	0.0154	0.0465	0.0188	0.0518	0.0731	0.0912	0.0117	0.0118
Poland	0.0725	0.0249	0.0151	0.0166	0.0120	0.0845	0.0327	0.0425	0.0100	0.0110
Portugal	0.1250	0.0265	0.0125	0.0211	0.0143	0.0192	0.0475	0.0634	0.0139	0.0146
Romania	0.0325	0.0219	0.0135	0.0093	0.0158	0.1103	0.0355	0.0456	0.0147	0.0154
Slovenia	0.0350	0.0175	0.0118	0.0179	0.0143	0.0704	0.0457	0.0584	0.0114	0.0115
Spain	0.3601	0.0327	0.0157	0.0232	0.0167	0.0437	0.0430	0.0568	0.0082	0.0088
Sweden	0.0750	0.0279	0.0151	0.0232	0.0150	0.0906	0.0481	0.0663	0.0105	0.0110
United Kingdom	0.3326	0.0365	0.0154	0.0194	0.0300	0.1057	0.0430	0.0608	0.0078	0.0083

According to Eq. (9-10), each element of the optimal alternative was determined. The results are presented in Table 9.

Table 9. Optimal alternative determination

Optimal alternative / Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
	max	**max**	**max**	**min**	**min**	**min**	**min**	**min**	**min**	**min**
	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
S	0.3601	0.0365	0.0166	0.0465	0.0375	0.1691	0.1108	0.1326	0.0448	0.0454

The decomposition of the optimal alternative was computed using Eqs. (11-12). The results are illustrated in Table 10.

Table 10. Decomposition of the optimal alternative

Optimal alternative / Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
	max	max	max	min	min	min	min	min	min	min
	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
S^{max}	0.3601	0.0365	0.0166							
S^{min}				0.0465	0.0375	0.1691	0.1108	0.1326	0.0448	0.0454

The decomposition of alternatives was calculated with Eqs. (13-14). In Table 11, the decomposition of each alternative is demonstrated.

Table 11. Decomposition of alternatives

Alternative / Criterion		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
		max	max	max	min	min	min	min	min	min	min
		t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Belgium	T_1^{max}	0.2851	0.0338	0.0119							
	T_1^{min}				0.0145	0.0333	0.0453	0.0352	0.0527	0.0105	0.0112
Bulgaria	T_2^{max}	0.0150	0.0200	0.0118							
	T_2^{min}				0.0179	0.0231	0.0317	0.0425	0.0509	0.0096	0.0102
Croatia	T_3^{max}	0.0175	0.0164	0.0118							
	T_3^{min}				0.0211	0.0115	0.1268	0.0515	0.0663	0.0092	0.0093
Cyprus	T_4^{max}	0.0300	0.0213	0.0119							
	T_4^{min}				0.0332	0.0231	0.1208	0.1108	0.1326	0.0448	0.0454
Denmark	T_5^{max}	0.0425	0.0295	0.0152							
	T_5^{min}				0.0291	0.0167	0.0540	0.0435	0.0634	0.0100	0.0101
Estonia	T_6^{max}	0.0200	0.0166	0.0125							
	T_6^{min}				0.0232	0.0176	0.0564	0.0778	0.0931	0.0130	0.0143
Finland	T_7^{max}	0.0750	0.0249	0.0148							
	T_7^{min}				0.0166	0.0176	0.1014	0.0293	0.0350	0.0086	0.0087
France	T_8^{max}	0.1776	0.0358	0.0156							
	T_8^{min}				0.0155	0.0231	0.0845	0.0451	0.0554	0.0085	0.0089
Germany	T_9^{max}	0.2976	0.0358	0.0166							
	T_9^{min}				0.0137	0.0200	0.1492	0.0302	0.0429	0.0096	0.0106
Greece	T_{10}^{max}	0.1375	0.0267	0.0145							
	T_{10}^{min}				0.0166	0.0136	0.0528	0.0703	0.0842	0.0175	0.0178
Italy	T_{11}^{max}	0.2351	0.0346	0.0157							
	T_{11}^{min}				0.0179	0.0115	0.0564	0.0406	0.0547	0.0109	0.0117
Latvia	T_{12}^{max}	0.0225	0.0154	0.0120							
	T_{12}^{min}				0.0166	0.0143	0.1409	0.0457	0.0547	0.0087	0.0088
Lithuania	T_{13}^{max}	0.0400	0.0181	0.0131							
	T_{13}^{min}				0.0291	0.0125	0.0453	0.0430	0.0521	0.0088	0.0090
Malta	T_{14}^{max}	0.0550	0.0158	0.0116							
	T_{14}^{min}				0.0179	0.0150	0.0497	0.0146	0.0175	0.0098	0.0100
Netherlands	T_{15}^{max}	0.3426	0.0347	0.0164							
	T_{15}^{min}				0.0179	0.0375	0.1691	0.0389	0.0608	0.0124	0.0146
Norway	T_{16}^{max}	0.0750	0.0259	0.0154							
	T_{16}^{min}				0.0465	0.0188	0.0518	0.0731	0.0912	0.0117	0.0118
Poland	T_{17}^{max}	0.0725	0.0249	0.0151							

	T_{17}^{min}				0.0166	0.0120	0.0845	0.0327	0.0425	0.0100	0.0110
Portugal	T_{18}^{max}	0.1250	0.0265	0.0125							
	T_{18}^{min}				0.0211	0.0143	0.0192	0.0475	0.0634	0.0139	0.0146
Romania	T_{19}^{max}	0.0325	0.0219	0.0135							
	T_{19}^{min}				0.0093	0.0158	0.1103	0.0355	0.0456	0.0147	0.0154
Slovenia	T_{20}^{max}	0.0350	0.0175	0.0118							
	T_{20}^{min}				0.0179	0.0143	0.0704	0.0457	0.0584	0.0114	0.0115
Spain	T_{21}^{max}	0.3601	0.0327	0.0157							
	T_{21}^{min}				0.0232	0.0167	0.0437	0.0430	0.0568	0.0082	0.0088
Sweden	T_{22}^{max}	0.0750	0.0279	0.0151							
	T_{22}^{min}				0.0232	0.0150	0.0906	0.0481	0.0663	0.0105	0.0110
United Kingdom	T_{23}^{max}	0.3326	0.0365	0.0154							
	T_{23}^{min}				0.0194	0.0300	0.1057	0.0430	0.0608	0.0078	0.0083

The intensity of the optimal alternative and alternatives was determined through Eqs. (15-18). The results are presented in Table 12.

Table 12. The intensity of the optimal alternative and the alternatives

Alternative	**max**	**min**
	S_k	***S_l***
	T_{ik}	***T_{il}***
S	0.4133	0.5867
Belgium	0.3307	0.2027
Bulgaria	0.0468	0.1859
Croatia	0.0457	0.2958
Cyprus	0.0632	0.5107
Denmark	0.0872	0.2267
Estonia	0.0491	0.2955
Finland	0.1147	0.2172
France	0.2289	0.2410
Germany	0.3500	0.2762
Greece	0.1788	0.2729
Italy	0.2854	0.2037
Latvia	0.0499	0.2897
Lithuania	0.0712	0.1997
Malta	0.0824	0.1345
Netherlands	0.3937	0.3512
Norway	0.1163	0.3049
Poland	0.1125	0.2093
Portugal	0.1640	0.1941
Romania	0.0679	0.2465
Slovenia	0.0643	0.2296
Spain	0.4085	0.2005
Sweden	0.1181	0.2648
United Kingdom	0.3845	0.2750

Based on Eqs. (19-22), the area corresponding to the optimal alternative and other alternatives was determined. The results are shown in Table 13.

Table 13. The area under the optimal alternative and the alternatives

Alternative	Area	Values
Optimal Alternative	F^{opt}	0.5000
Belgium	F_1	0.2667
Bulgaria	F_2	0.1164
Croatia	F_3	0.1707
Cyprus	F_4	0.2870
Denmark	F_5	0.1570
Estonia	F_6	0.1723
Finland	F_7	0.1660
France	F_8	0.2350
Germany	F_9	0.3131
Greece	F_{10}	0.2258
Italy	F_{11}	0.2446
Latvia	F_{12}	0.1698
Lithuania	F_{13}	0.1355
Malta	F_{14}	0.1085
Netherlands	F_{15}	0.3724
Norway	F_{16}	0.2106
Poland	F_{17}	0.1609
Portugal	F_{18}	0.1790
Romania	F_{19}	0.1572
Slovenia	F_{20}	0.1469
Spain	F_{21}	0.3045
Sweden	F_{22}	0.1914
United Kingdom	F_{23}	0.3298

The Magnitude of the Area of the Alternative is calculated using Eq. (23). Table 14 presents the Magnitude of the Area of the Alternatives along with the final ranking of the alternatives, which is determined in ascending order of M_i.

Table 14. The magnitude of the Area of Alternatives and the final ranking of the alternatives

Alternative	Magnitude of the Area of Alternative M_i	Values	Rank
Belgium	M_1	0.2333	6
Bulgaria	M_2	0.3836	22
Croatia	M_3	0.3293	14
Cyprus	M_4	0.2130	5
Denmark	M_5	0.3430	19
Estonia	M_6	0.3277	13
Finland	M_7	0.3340	16
France	M_8	0.2650	8
Germany	M_9	0.1869	3
Greece	M_{10}	0.2742	9
Italy	M_{11}	0.2554	7
Latvia	M_{12}	0.3302	15
Lithuania	M_{13}	0.3645	21
Malta	M_{14}	0.3915	23
Netherlands	M_{15}	0.1276	1
Norway	M_{16}	0.2894	10
Poland	M_{17}	0.3391	17
Portugal	M_{18}	0.3210	12
Romania	M_{19}	0.3428	18
Slovenia	M_{20}	0.3531	20
Spain	M_{21}	0.1955	4
Sweden	M_{22}	0.3086	11
United Kingdom	M_{23}	0.1702	2

The final ranking of the criteria is illustrated above. Countries with the lowest numerical values indicate the highest performance levels in terms of supply chain performance. The MARA results indicate that the Netherlands, the United Kingdom, Germany, Spain, and Cyprus exhibit the highest levels of supply chain performance. In contrast, Denmark, Slovenia, Lithuania, Bulgaria, and Malta rank the lowest. The overall ranking is as follows: the Netherlands > the United Kingdom > Germany > Spain > Cyprus > Belgium > Italy > France > Greece > Norway > Sweden > Portugal > Estonia > Croatia > Latvia > Finland > Poland > Romania > Denmark > Slovenia > Lithuania > Bulgaria > Malta.

3.3. Comparative Analysis

The SPC method is assessed in comparison with traditional techniques, specifically Entropy and CRITIC, as well as with novel approaches such as LOPCOW and MEREC, to determine the objective weights of criteria. Each method employs a unique approach and calculation process. For instance, the Entropy (Zou et al., 2006) and CRITIC (Diakoulaki et al., 1995) methods utilize a linear sum normalization procedure. In contrast, the LOPCOW (Ecer & Pamucar, 2022) and MEREC (Keshavarz-Ghorabaee et al., 2021) methods implement linear max-min normalization techniques to ascertain the criteria weights. In contrast, the SPC method evaluates weights based on the symmetry point of the criterion (Gligorić et al., 2023). Consequently, a comprehensive evaluation of the results was conducted. The weights of the criteria determined by each objective weighting method are illustrated in Table 15 and Figure 1.

Table 15. The ranking of the criteria based on various methods

Criterion	SPC		Entropy		CRITIC		LOPCOW		MEREC	
	Coefficient	Rank	Coefficient	Rank	Coefficient	Rank	Coefficient	Rank	Coefficient	Rank
C_1	0.1227	1	0.4276	1	0.1354	1	0.0739	10	0.1502	2
C_2	0.1027	9	0.0413	7	0.1335	2	0.0924	5	0.0699	9
C_3	0.0613	10	0.0082	10	0.1317	3	0.0886	7	0.0256	10
C_4	0.0933	5	0.0509	5	0.0738	10	0.1074	4	0.1305	3
C_5	0.1240	8	0.0453	6	0.1093	4	0.1090	3	0.0700	8
C_6	0.1213	2	0.1633	2	0.0863	7	0.0777	9	0.1093	4
C_7	0.1093	4	0.0883	4	0.0751	8	0.0910	6	0.0999	5
C_8	0.0747	3	0.0967	3	0.0750	9	0.0849	8	0.0964	6
C_9	0.0920	7	0.0387	9	0.0881	6	0.1387	1	0.1524	1
C_{10}	0.0987	6	0.0398	8	0.0919	5	0.1364	2	0.0957	7

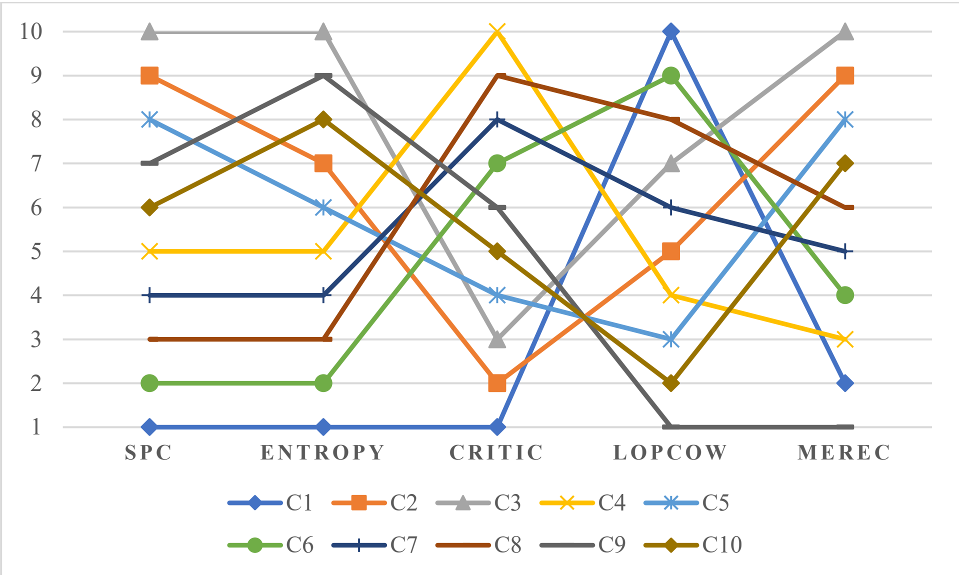

Figure 1. Comparison of the results from different weighting methods

The findings indicate that the method employed for weighting calculations can significantly influence the results. For instance, traditional methods (Entropy and CRITIC) identified “maritime connectivity” as the most important criterion. In contrast, novel approaches (LOPCOW and MEREC) highlighted “Mean consolidated export dwell time” as the crucial indicator for supply chain performance. Consequently, it can be concluded that the results are closely tied to the weighting method used and are pretty sensitive to these variations. The subsequent phase in the comparative analysis involves comparing the MARA method with well-known and traditional MCDM methods, including TOPSIS, COPRAS, CoCoSo, and WASPAS. It is important to note that the weights derived from the SPC method are utilized to calculate the final ranking of alternatives. The rankings produced by the various MCDM methods are illustrated in Figure 2.

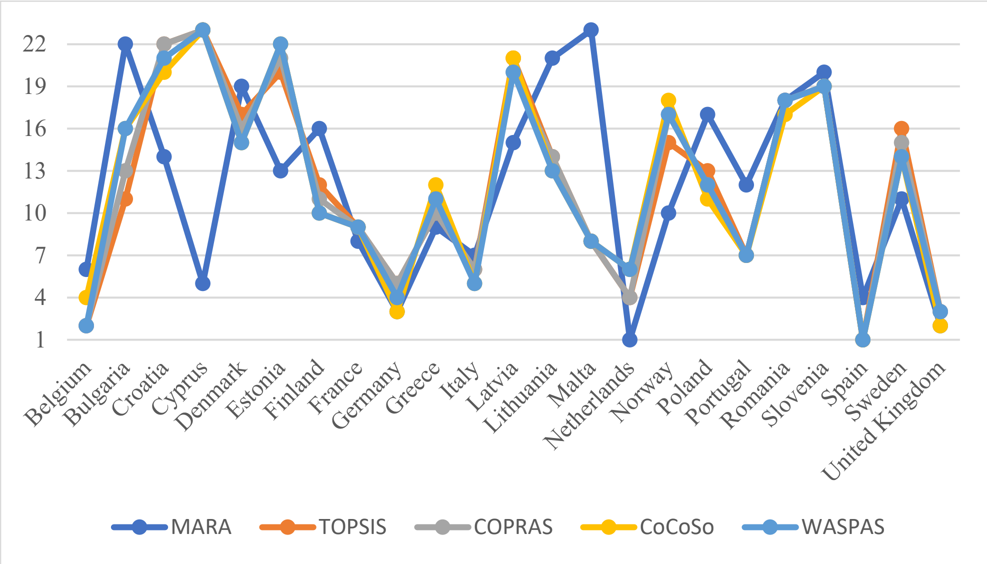

Figure 2. Comparison of rankings by different MCDM methods

The findings indicate that advanced economies, including Spain, the United Kingdom, Germany, Belgium, and the Netherlands, consistently demonstrated the strongest supply chain performance across all methods. Although rankings vary slightly depending on the method, the overall trend reflects a consistent pattern of the highest and lowest-performing countries.

5. DISCUSSION AND CONCLUSION

This paper integrates the SPC and the MARA methods to evaluate the supply chain performance of European countries. Since the evaluation of supply chain performance is influenced by numerous factors, a hybrid MCDM method was applied in this research. Focusing on European nations is justified due to their highly interconnected economies, significant cross-border trade, and the region's diverse economic landscapes, including highly industrialized nations and smaller developing economies. Data for European countries were obtained from the World Bank's (2023) report. Performance indicators for supply chains in European countries were established as evaluation criteria and adjusted according to their respective weights. The SPC method was employed to determine the criteria weights, while the MARA method was utilized to rank the countries. Additionally, a comparative analysis was conducted to test the robustness of the results.

Based on the SPC results, the rank of criteria weight is as follows: maritime connectivity (w_1=0.3601), mean delivery time for postal activities (w_6=0.1691), mean port import dwell time (w_8=0.1326), mean consolidated import dwell time (w_7=0.1108), mean turnaround time at port (w_4=0.0465), mean port export dwell time (w_{10}=0.0454), mean consolidated export dwell time (w_9=0.0448), mean aviation import dwell time (w_5=0.0375), aviation connectivity (w_2=0.0365), and postal connectivity (w_3=0.0166). Maritime connectivity emerged as the most significant criterion in the analysis. This finding underscores that the primary factor influencing the supply chain performance of European countries is the number of international direct connections available. The second most important criterion identified was the average delivery time for postal operations. Notably, the processing, handling, and transit times within domestic and international postal networks, as well as shorter delivery times, substantially impact overall supply chain performance. Moreover, the findings reveal that the average port import dwell time emerged as the most critical indicator. The findings suggest that the efficiency of port operations, customs processing, and logistics coordination, coupled with reduced dwell times, has significantly impacted supply chain performance. These findings are consistent with Kara et al. (2024), who found that maritime connectivity and mean delivery time for postal activities are crucial for measuring supply chain performance.

The MARA method was applied to evaluate the supply chain performance of European countries. The MARA rankings are as follows: the Netherlands (M_{15}=0.1276), the United Kingdom (M_{23}=0.1702), Germany (M_9=0.1869), Spain (M_{21}=0.1955), Cyprus (M_4=0.2130), Belgium (M_1=0.2333), Italy (M_{11}=0.2554), France (M_8=0.2650), Greece (M_{10}=0.2742), Norway (M_{16}=0.2894), Sweden (M_{22}=0.3086), Portugal (M_{18}=0.3210), Estonia (M_6=0.3277), Croatia (M_3=0.3293), Latvia (M_{12}=0.3302), Finland (M_7=0.3340), Poland (M_{17}=0.3391), Romania (M_{19}=0.3428), Denmark (M_5=0.3430), Slovenia (M_{20}=0.3531), Lithuania (M_{13}=0.3645), Bulgaria (M_2=0.3836), and Malta (M_{14}=0.3915). The results reveal that the Netherlands, the United Kingdom, Germany, Spain, and Cyprus achieved the highest levels of supply chain performance. At the same time, Denmark, Slovenia, Lithuania, Bulgaria, and Malta recorded the lowest performance. This finding can be explained by the fact that the Netherlands, the United Kingdom, Germany, and Spain likely excel due to their robust infrastructure, strategic geographic positions, and extensive trade networks. For example, prominent ports such as Rotterdam in the Netherlands and Hamburg in Germany, along with advanced technologies and efficient logistics systems, contribute to their high rankings. Interestingly, Cyprus outperformed other developed European nations, showcasing remarkable performance. In contrast, countries such as Slovenia, Lithuania, Bulgaria, and Malta face challenges due to inadequate infrastructure, more minor economic scales, and limited connectivity. The present finding is aligned with other research by Kara et al. (2024), which found that the Netherlands, the United Kingdom, and Spain achieved the highest supply chain performance.

The hybrid model was tested through a comparative analysis. Initially, a comparison with established methods was conducted to determine the criteria weights. Four additional weighting techniques—ENTROPY, CRITIC, LOPCOW, and MEREC—were utilized to evaluate and compare the results. This analysis revealed that the significance of the criteria fluctuates depending on the methods applied. These findings align with recent research (Jusufbašić, 2023; Štilić et al., 2023; Chatterjee & Chakraborty, 2024), which also noted variations in the rankings of criteria weights. Subsequently, a further comparative analysis was carried out to assess the stability of rankings across several MCDM methods, including TOPSIS, COPRAS, CoCoSo, and WASPAS. The results indicated that the ranking order produced by the proposed model closely matched those generated by the other MCDM methods. Furthermore, the countries with the highest and lowest levels of supply chain performance retained consistent rankings across all approaches. Overall, the comparative analysis results validated the hybrid model's effectiveness.

This study delineates the supply chain positions of various European nations. The findings from this research can serve as a valuable framework for these countries to enhance their supply chain performance. The following implications are proposed to assist European nations in achieving improved supply chain outcomes:

(i) Policymakers should focus on boosting international direct connections by enlarging port capacities, improving infrastructure, and establishing collaborations with global shipping firms.

(ii) To enhance port operations, it is essential for policymakers to prioritize effective practices, expedite customs clearance, and improve logistics coordination. Investing in advanced technologies, such as port community systems and real-time tracking technologies, can significantly reduce delays, shorten import dwell times, and enhance overall supply chain efficiency.

(iii) Postal services should improve the efficiency of processing, handling, and transportation. Leveraging emerging technologies such as Artificial Intelligence, Blockchain, and Big Data for route optimization and employing predictive analytics for demand forecasting can result in shorter and safer services.

(iv) European countries facing challenges in supply chain performance should focus on establishing regional partnerships to leverage the connectivity benefits offered by more efficient neighboring nations. By sharing best practices and engaging in regional infrastructure initiatives, less-connected countries can enhance their maritime and logistics capabilities.

It is important to recognize this study's limitations, even as it provides valuable insights into European countries' supply chain performance. It may not cover all dimensions of performance evaluation, suggesting that future research could benefit from exploring additional criteria. Furthermore, this study focuses exclusively on supply chain performance within Europe. While it thoroughly assesses various European nations, the findings may not apply to countries outside this region. Furthermore, incorporating an analysis of the European Green Deal initiatives can enhance the evaluation of the countries' green supply chain performance.

Disclosure Statements (Beyan ve Açıklamalar)

1. The author of this article confirm that their work complies with the principles of research and publication ethics (Bu çalışmanın yazarı, araştırma ve yayın etiği ilkelerine uyduğunu kabul etmektedir).

2. No potential conflict of interest was reported by the author (Yazar tarafından herhangi bir çıkar çatışması beyan edilmemiştir).

3. This article was screened for potential plagiarism using a plagiarism screening program (Bu çalışma, intihal tarama programı kullanılarak intihal taramasından geçirilmiştir).

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