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Evaluation of Supply Chain Resilience in N-11 Countries by MEREC Based EDAS, MARCOS, WASPAS Integrated Method

N-11 Ülkelerinde Tedarik Zinciri Dayanıklılığının MEREC Tabanlı EDAS, MARCOS, WASPAS Bütünleşik Yöntemiyle Değerlendirilmesi

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ABSTRACT

Supply chain resilience is an important factor in ensuring the growth and development of economies, as well as profitable operations in businesses. Because, unstable supply chains can cause an increase in operational costs, loss of workforce, and a decrease in economic mobility as a result of possible disruptions. In this study, supply chain resilience was evaluated considering the potential of N-11 countries. The Global Resilience Index data published by FM Global was used in the evaluation process, and the weights of the indicators related to the resilience of the supply chain were determined by the MEREC method. The relative rankings of the countries were then determined by the EDAS, MARCOS, and WASPAS methods. The resulting rankings were combined with the BORDA counting method to form the final rankings for supply chain resilience of N-11 countries. The focus on the subject and the methods used have given the research a unique identity. As a result of the calculations, Supply Chain Visibility and Corporate Governance indicators stand out as the most important indicators affecting supply chain resilience in N-11 countries, while South Korea and Türkiye are the two best countries in terms of supply chain resilience among N-11 countries. Various suggestions were made to researchers and practitioners in line with the findings.

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ÖZ

Tedarik zinciri dayanıklılığı, işletmelerde operasyonların kârlı bir şekilde gerçekleştirilebilmesinin yanı sıra ekonomilerde de büyümenin ve kalkınmanın sağlanabilmesinde önemli bir faktördür. Zira dayanıksız tedarik zincirleri, olası aksaklıklar neticesinde operasyon maliyetlerinin yükselmesine, iş gücü kaybına ve ekonomik hareketliliğin azalmasına neden olabil-

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mektedir. Bu çalışmada N-11 ülkelerinin sahip olduğu potansiyel göz önünde bulundurularak tedarik zinciri dayanıklılıkları değerlendirilmiştir. Değerlendirme işleminde FM Global adlı kuruluş tarafından yayınlanan Küresel Dayanıklılık İndeksi verileri kullanılmış olup tedarik zinciri dayanıklılığına ilişkin göstergelerin ağırlıkları MEREC yöntemiyle, ülkelerin görece sıralamaları EDAS, MARCOS ve WASPAS yöntemleriyle belirlenmiştir. Elde edilen sıralamalar BORDA sayım yöntemiyle birleştirilerek N-11 ülkelerinin tedarik zinciri dayanıklılığına ilişkin nihai sıralamaları oluşturulmuştur. Odaklanılan konu ve kullanılan yöntemler, araştırmaya özgün bir kimlik kazandırmaktadır. Yapılan hesaplamalar sonucunda Tedarik Zinciri Görünürlüğü ve Kurumsal Yönetim göstergeleri N-11 ülkelerinde tedarik zinciri dayanıklılığını etkileyen en önemli göstergeler olarak ön plana çıkarken Güney Kore ve Türkiye'nin N-11 ülkeleri arasında tedarik zinciri dayanıklılığı bakımından en iyi iki ülke olduğu görülmüştür. Elde edilen bulgular doğrultusunda araştırmacılara ve uygulayıcılara çeşitli önerilerde bulunulmuştur.

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1. INTRODUCTION

Supply chains are networks of processes that involve stakeholders from different regions to produce and deliver final products or services to customers. These networks enable organizations with diverse structures and cultures to collaborate commercially and produce products and services that meet customer expectations under the most suitable conditions. Due to their impact on trade volumes, supply chains are regarded as one of the most crucial drivers of regional and global economic growth and development. As a matter of fact, disruptions in supply chains can create bottlenecks that have negative effects on economic productivity and growth. (Goel et al., 2021).

Despite limited resources, organizations are facing increasing customer requirements and shortening product life cycles, which are driving them to work in an integrated manner within supply chains. However, the competitive pressure caused by globalization is leading to the expansion of supply chain networks across the world. This situation transforms supply chains into complex structures and exposes them to various risk factors (Wagner & Bode, 2006). Furthermore, changing customer demands and global economic trends increase market uncertainty and diversify the associated risks, making the consequences of supply chain disruptions devastating. Therefore, the resilience of supply chain operations against potential disruptions is a critical issue that both managers and researchers are highly sensitive to.

Supply chain resilience refers to the ability of the chain to sustain operations continuously in the face of uncertainty and disruption. It encompasses the capacity of the supply chain to prepare for potential interruptions, react in a cost-effective manner in case of an interruption, and recover promptly (Ponomarov & Holcomb 2009). Thus, achieving supply chain resilience necessitates an approach that encompasses all stages and actors within the chain. Increasing flexibility in physical, financial, and operational aspects is a prerequisite for enhancing supply chain resilience, and this can only be accomplished through a comprehensive approach. For this approach to be implemented successfully, it is necessary to closely monitor all elements that have the potential to affect the supply chain, as well as supply chain activities.

Supply chain resilience has the potential to improve the profitability of supply chain operations by enhancing trust among supply chain actors and meeting customer expectations. However, in today's economic landscape, supply chains are connected on a global scale, resulting in unprecedented complexity in the flow of finished and semi-finished products. This flow increases the vulnerability of supply chains, giving rise to numerous risks and vulnerabilities. (Wagner & Bode, 2006). This situation compels organizations to adopt strategies aimed at enhancing the resilience of their supply chains. These strategies should enable the chain to remain resilient in the event of possible disruptions and quickly adapt to changing market conditions. However, the impact of these strategies may vary depending on the geographic conditions where the supply chain is operating (Gunasekaran et al., 2015). For instance, long-term strategies such as investing in new technologies may yield desirable outcomes for organizations operating in a stable economy, while shorter-term strategies like reducing costs or inventories may prove successful for organizations operating in volatile regions. Similarly, organizations operating in a trust-based cultural environment may opt for long-term strategies, whereas those operating in cultural conflict zones may prefer short-term strategies. Hence, managers seeking to enhance the resilience of their supply chains should closely monitor the dynamics of the regions in which they operate.

Unstable supply chains can impede economic development by causing financial losses, demand and supply mismatches, and destabilization of operational policies in production, distribution, and inventory control due to possible disruptions (Ivanov, 2021). Therefore, monitoring and enhancing the resilience of supply chains is a crucial issue for policymakers. Additionally, policymakers should remain vigilant to potential problems and closely monitor the potential impact of changes in the global economic landscape on supply chains. This will help reduce supply chain risks and ensure uninterrupted access to the goods and services necessary for the citizens of the country.

Despite the significant impact of supply chain resilience on national economies, most research in this field focuses solely on its business aspect. For instance, Roberta Pereria et al. (2014) studied the identification of internal and inter-institutional problems that impact supply chain resilience, while Scholten and Schilder (2015) explored the role of cooperation in enhancing supply chain resilience. This creates a gap in the literature that neglects the national dimension of supply chain resilience. The main reason for this approach is the difficulty and complexity of measuring supply chain resilience at the national level. Nevertheless, despite the challenges involved, it remains crucial to address supply chain resilience at the national level. Therefore, this study aims to address this gap by examining the supply chain resilience of N-11 countries. These countries have the potential to become important supply centers in the future due to their resources and socioeconomic characteristics. In this context, in this study, the resilience of the supply chain of these countries was evaluated with multi-criteria decision-making (MCDM) methods using data on the supply chain section of the Global Resilience Index published by FM Global.

In the evaluation process, the weights of the indicators related to supply chain durability were determined by the MEREC method, and the supply chain durability rankings of the countries were determined separately with the EDAS, MARCOS and WASPAS methods. The rankings obtained later were combined with the BORDA counting method to form the final rankings of the countries. Thus, a study was carried out to fill the gap in the supply chain durability literature, and the decision-making literature was tried to be enriched by using current MCDM methods together. In this context, in the following parts of the study, firstly, the durability of the supply chain is discussed in general terms and the literature is summarized, then the methods used in the study are explained and the calculation results for these methods are reported. Finally, the findings were interpreted, and various suggestions were made to researchers and practitioners.

2. SUPPLY CHAIN RESILIENCE

Supply chain resilience is an indicator of organizations' ability to identify bottlenecks and potential risks related to the supply chain management process (Brandon-Jones et al., 2014). For this reason, in today's business environment where uncertainty and complexity are increasing, it is one of the issues that organizations should focus on to continue their activities uninterruptedly. Likewise, the durability of the supply chain allows the flow of semi-finished and finished products to continue, even in the event of unexpected and devastating changes at any point in the supply chain, making it possible for organizations to fulfill their commitments despite the problems experienced in the markets.

Supply chain resilience is a subject that is still being debated, with no clear definition available in the literature. Sprecher et al. (2015) suggest that supply chain resilience is the ability to obtain enough of a particular material to meet societal demands and to offer suitable alternatives if there is an inadequate supply. Ponomarov and Holcomb (2009) define supply chain resilience as the ability of the supply chain to be ready for unexpected disruptions and to maintain the continuity of operations at the desired level of control in case of interruptions. Similarly, Spiegler et al. (2012) view supply chain resilience as the adaptive capacity of the supply chain to plan for unforeseen events, respond to disruptions, and recover from them while maintaining continuity. Scholten et al. (2014) view supply chain resilience as a proactive approach to managing risks, defining it as the ability to respond to disruptions in the supply chain. This perspective emphasizes the importance of being prepared for unexpected events and having a plan in place to mitigate the impact of disruptions. From a slightly different perspective, Hearnshaw and Wilson (2013) view supply chain resilience as the ability to quickly recover from disruptions and to minimize the impact of these disruptions on customers. Sheffi (2015) presents a broader perspective on supply chain resilience, defining it as the ability to cope with the complexity of supply chains and to adapt to new challenges using a perspective that surpasses the constraints of traditional approaches.

Although supply chain resilience is discussed from different perspectives in the literature, these perspectives converge on the fact that the supply chain is resilient against disruptions and that it allows sufficient flow of finished and semi-finished products by quickly recovering in the face of possible adversities. In this context, for the purposes of this study, supply chain resilience is defined as the capacity of a supply chain to maintain the flow of finished and semi-finished products in the most economical way without interruption in the face of unexpected events.

The traditional approach to supply chain design is centered on efficiency and maximizing profitability by reducing waste. However, this narrow focus on efficiency can result in reduced flexibility and increased vulnerability in supply chains. Backup inventory or backup supplier policies need to be considered so that supply chains can be designed to absorb unexpected outages and quickly restore operations in the event of serious disruptions. However, these policies come with a cost, which can increase overall supply chain costs. Therefore, it is important to adopt an approach that balances these two extremes to increase supply chain performance to the desired level (Pettit et al., 2010). Despite efforts to make supply chains more flexible, the risk of disruption always exists. If the cost of mitigating this risk is too high, it may become unsustainable for organizations to continue their operations.

It is important for supply chains to be resilient in today's market conditions where customer requirements are unpredictable and variable. This requires a combination of strategic practices such as shortening lead times, developing advanced cooperation with flexible suppliers, and ensuring integration between chain members. In addition, buffer capacity and risk inventory should be integrated into supply chain strategies to ensure operational continuity and meet demand even in cases of interruption. The combination of reactive and proactive capabilities can enable the supply chain to quickly return to its normal flow in the face of possible problems and even improve its performance above the previous level (Ivanov, 2021). However, the level of performance and recovery time after disruption depends on the level of proactive and reactive capabilities of the chain, which can vary among organizations. Figure 1 provides a schematic representation of this process.

Although supply chains are organized in different structures by different organizations, they interact with each other. A disruption in a supply chain not only causes disruptions in the related chain but can also trigger disruptions in other supply chains that are connected to it. With the spillover effect, delivery delays may result in negative consequences such as loss of revenue, loss of market share and reputation, and loss of value in stocks (Hendricks & Singhal, 2005). Small disruptions in the supply chain can have significant consequences due to the spillover effect. Therefore, to increase supply chain resilience, it is important to carefully examine and monitor even minor interruptions (Dolgui et al., 2018), and enhance visibility throughout the supply chain (Ivanov, 2021).

Uninterrupted monitoring of flow in the supply chain increases visibility, allowing supply chain members to better deal with uncertainty (Ponomarov & Holcomb 2009). However, monitoring supply chains, which are becoming increasingly complex, is not an easy task. Technological innovations such as big data and the internet of things can make it easier to monitor supply chains, but their impact on improving supply chain resilience is limited. Supply chain transparency and collaboration, along with proactive management strategies, can significantly contribute to supply chain resilience by facilitating coping with interruptions (Gunasekaran et al., 2015).

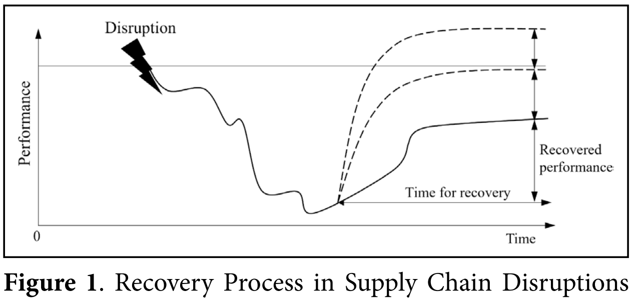

Figure 1. Recovery Process in Supply Chain Disruptions (Ivanov, 2021).

Supply chains are one of the main sources of business mobility and economic development. For this reason, disruptions that may occur in supply chains have the potential to affect not only the organizations in the relevant supply chains, but also the economy in which the supply chain is organized. Disruptions in supply chains can cause serious problems in the country's economy in the long run (Hendricks & Singhal, 2005). In addition, the uninterrupted meeting of the basic needs of the society in times of crisis depends on the durability of the supply chains. For this reason, supply chain resilience is of critical importance for the continuity of corporate and economic activities as well as the continuity of life. Likewise, in countries with durable supply chain networks, during periods of natural disasters such as earthquakes, floods, and fires, critically important vital products are delivered to the points where they are needed, and crises are managed more effectively (Ivanov, 2021).

2.1. Literature

Supply chain resilience is one of the topics that attract the attention of researchers working in the field of supply chain due to its increasing importance recently. In this context, researches on supply chain resilience and quantitative decision-making methods in national and international data sources have been scanned, prominent studies and issues related to these studies are given below.

Falasca et al. (2008) proposed a simulation-based framework in their study where they evaluated the resilience of supply chains against natural disasters. In their study, they concluded that density, complexity, and node criticality are determinants of supply chain resilience to natural disasters.

Soni et al. (2014) proposed a deterministic modeling in their study to measure supply chain resilience. They argued that this proposed model will enable managers to make comparisons between different supply chains, as well as to monitor the factors affecting supply chain resilience.

Timperio et al. (2016) used geographic information system and Fuzzy AHP methods in their study to determine the most appropriate facility location to ensure resilience in disaster relief supply chains. In their study, they emphasized the importance of the distribution center location for a supply chain network to be resilient enough to allow decision makers to carry out rescue operations as quickly as possible.

Wicher et al. (2016) used the Fuzzy ANP method in their research to measure resilience in metallurgical supply chains. Considering the criteria of cooperation, flexibility, visibility, and financial strength, they argued that the measurement model they proposed, based on the findings they obtained as a result of the measurement, would be an effective tool in monitoring the resilience of the metallurgical supply chain.

Jafarnejad et al. (2019) used the Hesitant Fuzzy Delphi method in their study to investigate the main factors affecting the resilience of the medical equipment supply chain and to examine the dynamic relationships between these factors. As a result of their research, they concluded that ten main factors affect the supply chain resilience of medical equipment: agility, collaboration between supply chain actors, information sharing and trust, transparency of the supply chain, risk management culture, adaptability, structure, financing, and environmental conditions.

Rehman and Ali (2021) used Fuzzy AHP, Fuzzy TOPSIS and Fuzzy QFD methods in an integrated way in their work on prioritizing resilience strategies in health supply chains. As a result of their research, they revealed that Industry 4.0, multiple sourcing, risk awareness, agility and global diversification strategies are the most important strategies that increase resilience in healthcare supply chains.

Zhang et al. (2021) used Fuzzy AHP and Fuzzy TOPSIS methods together in their study where they examined the balance of resilience in the supply chains of cross-border e-commerce businesses. In line with their findings, they argued that resilience should be kept in an appropriate state of balance, rather than pursuing high resilience or low fragility.

Das et al. (2022) used AHP and DEMATEL methods in their studies on the effects of the Covid-19 outbreak on supply chain resilience. As a result of their research, they concluded that the most important factor in reducing the security vulnerabilities of the supply chain network is cost optimization, and government supports are the approach that can solve the problems that disturb the supply chains in the most effective way.

Belhadi et al. (2022) evaluated artificial intelligence applications used in strategies to increase supply chain resilience by integrating artificial neural networks and MCDM methods. From data collected from 479 manufacturing businesses, they suggested that fuzzy logic programming, machine learning big data, and agent-based systems are the best techniques to support strategies for supply chain resilience.

Wen and Liao (2022) proposed a new decision-making algorithm by integrating gained and lost dominance score method and personalized quantifiers with cubic spline interpolation in their study on the selection of policy recommendations to increase supply chain resilience under the effects of the Covid-19 epidemic. They demonstrated the superiority of the proposed algorithm with a sensitivity analysis and comparison analysis on a case study.

Banerjee et al. (2022) used the Gray DEMATEL method in their study to identify the barriers to building supply chain resilience in post-Covid-19 Indian SMEs and to explain the contextual relationship between them. As a result of their research, they concluded that lack of flexibility is the most critical causal barrier to building a resilient supply chain. They also drew attention to the lack of planning regarding resource management.

Pia et al. (2022) used Fuzzy ISM and DEMATEL methods in an integrated way in their study where they discussed the factors that determine supply chain resilience in the oil and natural gas industry during the Covid-19 epidemic. As a result of their research, they suggested that government support and security are the main drivers of supply chain resilience. They also concluded that collaboration and knowledge sharing among supply chain members are critical to supply chain resilience.

Hsu et al. (2022) used the MCDM and Quality House approach by integrating it in their study focusing on factors that increase supply chain resilience and reduce sustainable supply chain risks. In their application on one of China's largest relay manufacturers, they concluded that risks related to IT infrastructure and information system efficiency, customer supply disruptions, transportation disruptions, natural disasters and government instability were the most influential factors on supply chain resilience.

As it can be understood from the literature summary above, researches on supply chain resilience are carried out by focusing on businesses, and the general situation of countries is neglected. To contribute to filling this gap in the literature, this research focuses on supply chain resilience of N-11 countries. In this context, the methods used in the study are explained below.

3. METHODOLOGY

In this section, the data of N-11 countries on supply chain resilience, the methods used in the research and the reasons for choosing these methods are given.

The national aspect of supply chain resilience is an under-researched topic, and as a result, the FM Global Resilience Index is currently the only tool available to measure national supply chain resilience. Therefore, this index was utilized in this study. The evaluation process aimed to use current objective MCDM methods, for which MEREC, EDAS, MARCOS, and WASPAS methods were preferred. To mitigate any differences arising from the algorithms of these methods, the results obtained were combined using the BORDA Counting Method. The data and methods used in the research are discussed in detail below.

3.1. Data

Currently, there is no index or database that directly measures and evaluates the supply chain resilience of countries. Despite the lack of a direct index or database to measure and evaluate the supply chain resilience of countries, FM Global, an international insurance company, offers a measurement tool known as the Resilience Index. This tool aims to demonstrate a country's resilience against unexpected and destructive events and comprises three dimensions: economic, risk quality, and supply chain. The supply chain dimension of the index in question is a measurement tool that demonstrates the resilience of the supply chains of countries. Therefore, the supply chain dimension of the FM Global Resilience Index was utilized in this research. In this context, Table 1 presents the FM Global Resilience Index indicators used to evaluate the supply chain resilience of N-11 countries and the codes assigned to these indicators (FM Global, 2022).

The FM Global Resilience Index measures the resilience of countries' supply chains by compiling data shared by the World Bank and the World Economic Forum. The indicators used in the measurement process can take values between 0 and 100. The scores of the N-11 countries, which are the subject of this research, regarding the supply chain resilience indicators are presented in Table 2.

The data presented in Table 2 were obtained from the 2022 report of the Global Resilience Index and were accepted as the basic dataset within the scope of the research.

3.2. Method

In this part of the research, the methods used in the evaluation of supply chain resilience of N-11 countries are discussed. During the evaluation process, the weights of the indicators were established using the MEREC method, while the supply chain resilience performances of the countries were assessed through three distinct approaches: EDAS, MARCOS, and WASPAS. Then, the rankings obtained from the application of these methods were combined with the BORDA Count Method to form the final ranking. Explanations about the methods used in the research are given below.

Table 1. Supply Chain Resilience Indicators and Codes

Indicators	Codes
Control of Corruption	C_1
Infrastructure Quality	C^2
Corporate Governance	C^3
Supply Chain Visibility	C^4
Supply Chain Timeliness	C^5

3.2.1. MEREC Method

MEREC Method, introduced to the literature by Keshavarz Ghorabaee et al. in 2021, is an objective criterion weighting method. In the process of determining the criterion weights, it takes advantage of the impact of each criterion on the overall performance of the alternatives (Şahin, 2022). The criterion that has the most significant effect on alternative performance is assigned the highest weight if removed. In this method, the effect of removing each criterion is determined by the absolute deviation, which is the difference between the overall performance of the alternative and its performance if the criterion is removed. This approach distinguishes MEREC from other weighting methods. The steps of the method are as follows (Keshavarz Ghorabaee et al., 2021).

Step 1: The decision matrix for the problem is created. This matrix represents the performance scores of n alternatives for m criteria and is expressed in the form of equation (1).

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{ni} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Step 2: To get rid of the effect of value range differences and criterion units, the decision matrix is normalized by means of equation (2). The new values obtained are between 0 and 1.

Table 2. N-11 Countries Indicator Scores on Supply Chain Resilience

N-11 Countries	Supply Chain Resilience Indicators				
	C_1	C_2	C_3	C_4	C_5
Bangladesh	35,3797	15,1938	47,0075	34,3163	37,3637
Egypt	67,3353	19,4906	64,3662	31,728	48,7696
Indonesia	59,5835	30,3565	65,6898	56,3081	68,7901
Iran	55,2474	12,3961	22,898	33,535	55,5691
Mexico	66,4529	18,6043	65,4598	43,7028	62,894
Nigeria	18,7105	12,0977	68,9604	30,0341	43,4584
Pakistan	41,8203	18,7951	69,0096	12,1302	26,3927
Philippines	45,1319	28,1575	48,2889	46,0242	39,8887
South Korea	95,1011	59,7367	83,0357	75,7002	79,3242
Türkiye	69,1152	31,8352	73,1571	53,4494	67,0442
Vietnam	56,9438	31,5238	46,7067	62,7041	68,8932

$$n_{ij}^{x} = \begin{cases} \frac{\min_k x_{kj}}{x_{ij}}; \text{ If cost criterion} \\ \frac{x_{ij}}{max_k x_{kj}}; \text{ If benefit criterion} \end{cases} \quad (2)$$

Step 3: The overall performances of the alternatives are calculated by equation (3). In the MEREC method, a logarithmic measure with equal criterion weights is applied to obtain the overall performances of the alternatives. This measure is based on a non-linear function.

$$S_i = ln\left(1 + \left(\frac{1}{m}\sum_j |ln(n_{ij}^{x})|\right)\right) \quad (3)$$

Step 4: The performance values of the alternatives are calculated by using equation (4) for each criterion when removed. In this process, as in the previous step, a logarithmic measure is used.

$$S'_{ij} = ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} |ln(n_{ik}^{x})|\right)\right) \quad (4)$$

Step 5: The sum of absolute deviations (E_j) for each criterion is calculated using equation (5). The obtained values show the removal effect of the criteria.

$$E_j = \sum_i |S'_{ij} - S_i| \quad (5)$$

Step 6: The final weight (w_j) of each criterion is calculated using equation (6), while considering the removal effect of the criteria.

$$w_j = \frac{E_j}{\sum_k E_k} \quad (6)$$

3.2.2. EDAS Method

EDAS Method is a method introduced to the literature by Keshavarz Ghorabaee et al. in 2015. This method evaluates by considering the distance from the mean solution (Keshavarz Ghorabaee et al., 2015). In this respect, it differs from other MCDM methods. It is particularly useful in situations where the characteristics of the alternatives conflict with each other (Alinezhad & Khalili, 2019).

In the EDAS method, there are two criteria: positive distance from the mean (PDA) and negative distance from the mean (NDA). High PDA value and low NDA value indicate that the alternative is better than the average solution (Karabasevic et al., 2018). In this context, it is desired that the alternatives evaluated have PDA values as high as possible and NDA values as low as possible. The steps for applying the method are as follows (Keshavarz Ghorabaee et al., 2015):

Step 1: The most important criteria that define the alternatives are determined. In this step, it is determined by which criteria the alternatives for the decision problem to be addressed will be evaluated.

Step 2: The decision matrix is created. The matrix illustrates the performance of n alternatives on m evaluation criteria and takes the form of equation (7).

$$X[X_{ij}]_{nxm} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (7)$$

Step 3: The average solution matrix (AV) is created by considering all the criteria. This matrix is the average of the scores of the alternatives regarding the evaluation criteria and has the form of equality (8).

$$AV = [AV_j]_{1xm} \quad (8)$$

AV_j, represents the mean solution for each criterion and is calculated using equation (9).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n} \quad (9)$$

Step 4: A matrix of positive distance from the mean (PDA) and a matrix of negative distance from the mean (NDA) are formed. These matrices have the form of equality (10) and equation (11), respectively.

$$PDA = [PDA_{ij}]_{nxm} \quad (10)$$

$$NDA = [NDA_{ij}]_{nxm} \quad (11)$$

PDA_{ij}, shows the positive distance of the ith alternative from the mean solution for the jth criterion. It is calculated using equation (12) if the criterion j is benefit-based, and equation (13) if it is cost-based. Similarly, NDA_{ij} shows the negative distance of the i-th alternative from the mean solution for criterion j. It is calculated using equation (14) if the criterion j is benefit-based, and equation (15) if it is cost-based.

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad (12)$$

$$PDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad (13)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - X_{ij}))}{AV_j} \quad (14)$$

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \quad (15)$$

Step 5: The predetermined criterion weight values (wj) for each alternative are considered and the weighted total positive distance value (SP_i) is calculated using equation (16) and the weighted total negative distance value (SN_i) is calculated using equation (17).

$$SP_i = \sum_{i=1}^{m} w_j PDA_{ij} \quad (16)$$

$$SN_i = \sum_{i=1}^{m} w_j NDA_{ij} \quad (17)$$

Step 6: NSP_i and NSN_i values are calculated by normalizing the SP_i and SN_i values of the alternatives using the equations (18) and (19).

$$NSP_i = \frac{SP_i}{max_i(SP_i)} \quad (18)$$

$$NSN_i = 1 - \frac{SN_i}{max_i(SN_i)} \quad (19)$$

Step 7: Appraisal score (AS) for all alternatives are calculated using equation (20). The calculated AS values range from 0 to 1.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (20)$$

Step 8: Alternatives are ranked according to their AS values from largest to smallest. The alternative with the highest AS value is considered as the best alternative.

3.2.3. MARCOS Method

MARCOS method was developed in 2020 by Stević et al. as an objective MCDM method based on defining the relationship between alternatives and reference values. In the MARCOS method, a consensus ranking is created by determining the positions of the alternatives according to the ideal and anti-ideal solutions (Çınaroğlu, 2021). The best alternative is determined as the one that is closest to the ideal solution and farthest from the anti-ideal solution (Şahin, 2022). The solution steps of the MARCOS method are as follows (Stević et al., 2020):

Step 1: An initial decision matrix is created showing the performance of m alternatives for the decision problem in terms of n evaluation criteria.

Step 2: The expanded initial matrix is created by defining the ideal and anti-ideal solutions. This matrix is the initial decision matrix with the ideal (AI) and anti-ideal (AAI) solution rows added. The matrix structure is represented by equation (21).

$$X = \begin{matrix} AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{matrix} \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \quad (21)$$

The AI and AAI solutions added to the matrix are calculated using equations 22 and 23, depending on whether the criteria are benefit (B) or cost (C) features.

$$AAI = min_i x_{ij} \text{ if } j \in B \text{ and } max_i x_{ij} \text{ if } j \in C \quad (22)$$

$$AI = max_i x_{ij} \text{ if } j \in B \text{ and } min_i x_{ij} \text{ if } j \in C \quad (23)$$

Step 3: The expanded initial matrix is normalized using equations (24) and (25), which depend on the characteristics of the criteria being evaluated.

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ eğer } j \in C \quad (24)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ eğer } j \in B \quad (25)$$

where elements x_{ij} and x_{ai} represent the elements of the matrix X.

Step 4: Using equation (26), the weighted matrix $V=[v_{ij}]_{m\times n}$ is created.

$$v_{ij} = n_{ij} \times w_j \quad (26)$$

Step 5: The utility degree of the alternatives (K_i) is calculated. During this process, equation (27) is used for the distances of the alternatives from the anti-ideal solution, and equation (28) is used for the distances from the ideal solution.

$$K_i^- = \frac{S_i}{S_{aai}} \quad (27)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (28)$$

Where S_i (i=1,2,…,m) represents the sum of the weighted matrix V elements, which is calculated using equation (29).

$$S_i = \sum_{i=1}^{n} v_{ij} \quad (29)$$

Step 6: The utility function ($f(K_i)$), which determines the distances of the alternatives from the ideal and anti-ideal solution, is calculated using equation (30).

$$f(K_i) = \frac{K_i^- + K_i^+}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \quad (30)$$

Where $f(K_i^-)$ represents the utility function according to the anti-ideal solution and is determined using equation (31). Similarly, $f(K_i^+)$ represents the utility function according to the ideal solution and is determined by means of equation (32).

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (31)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (32)$$

Step 7: The alternatives are ranked based on the values of their utility functions. The alternative with the highest utility function value is considered the most suitable alternative.

3.2.4. WASPAS Method

The WASPAS method is an MCDM method that performs alternative ordering of decision problems by combining the Weighted Sum and Weighted Product methods. The method, developed by Zavadskas et al. in 2012, has been widely used in the literature for solving various decision problems. The WASPAS method aims to achieve a high level of consistency by optimizing the weighted integrated function (Lashgari et al., 2014). The solution steps of the method are as follows (Zavadskas et al., 2012):

Step 1: A decision matrix is created, which shows the performance of m alternatives in terms of n evaluation criteria and is represented in the form of equation (33).

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (33)$$

Step 2: The decision matrix is normalized. During this process, equation (34) is used for benefit criteria and equation (35) is used for cost criteria. The new matrix to be obtained is in the form of equation (36).

$$\bar{x}_{ij} = \frac{x_{ij}}{max_i x_{ij}} \quad (34)$$

$$\bar{x}_{ij} = \frac{min_i x_{ij}}{x_{ij}} \quad (35)$$

$$\bar{X} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{bmatrix} \quad (36)$$

Step 3: Evaluation score is calculated for each ith alternative using the weighted sum method. This is done using equation (37).

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij} \times w_j \quad (37)$$

where, w_j shows the weight value of the j criterion, and $Q_i^{(1)}$ shows the evaluation score calculated according to the weighted sum method of the ith alternative.

Step 4: Evaluation score is calculated for each ith alternative using the weighted product method. This is done using equation (38).

$$Q_i^{(2)} = \prod_{j=1}^{n} \bar{x}_{ij}^{\,w_j} \quad (38)$$

Step 5: The weighted common criterion value(Q_i) of each alternative is calculated by combining the evaluation scores calculated with the weighted sum and weighted product methods. This operation is performed using equation (39). The alternative with the highest Q_i value is the best alternative.

$$Q_i = 0{,}5Q_i^{(1)} + 0{,}5Q_i^{(2)} = \left[0{,}5 \times \left(\sum_{j=1}^{n} \bar{x}_{ij} \times w_j\right)\right] + \left[0{,}5 \times \left(\prod_{j=1}^{n} \bar{x}_{ij}^{\,w_j}\right)\right] \quad (39)$$

Equation 40 is used when it is not desired to give equal importance to weighted sum and weighted multiplication methods in the integration process.

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} = \left[\lambda \times \left(\sum_{j=1}^{n} \bar{x}_{ij} \times w_j\right)\right] + (1-\lambda)\left[0{,}5 \times \left(\prod_{j=1}^{n} \bar{x}_{ij}^{\,w_j}\right)\right] \quad (40)$$

where λ can take a value between 0 and 1 and this value is determined by the decision maker. If it is 0, the evaluation process turns into the weighted product method, and if it is 1, it turns into the weighted sum method.

3.2.5. BORDA Count Method

The BORDA count method is a method that combines two or more ranking lists to form a single ranking list. In this method, the scores are determined by assigning zero points to the least preferred alternative by the decision maker, one point to the next most preferred alternative, and so on up to n-1 points to the most preferred alternative. Then, the BORDA scores of all the ranking lists of the alternatives are summed and the final BORDA scores of the alternatives are calculated. (Lansdowne & Woodward, 1996). As a result of the calculation, the alternative with the highest final BORDA value is the best alternative.

4. APPLICATION AND RESULTS

In the first stage of the evaluation process, the weights of the indicators related to the resilience of the supply chain were determined using the MEREC method. Firstly, a decision matrix with the form of equality (1) was created by using the scores of N-11 countries in Table 2 related to the durability of the supply chain. Then, the created decision matrix was normalized using equation (2), and Table 3 was obtained.

The solution steps of the MEREC method were continued after normalizing the decision matrix. The overall performance scores of the alternatives were calculated using equation (3). Then, the performance scores of the alternatives were calculated if each criterion was removed using equation (4). The results of these calculations are presented in Table 4.

The MEREC method calculates the criteria weights by considering the changes that would occur in the performance scores of the alternatives if the criteria were removed. In this context, the absolute deviation (E_j) values of the criteria were calculated using equation (5), and the weights (w_j) of the criteria were calculated using equation (6), considering the scores in Table 4. The results of the calculations are given in Table 5.

As can be seen from Table 5, according to the MEREC method, supply chain resilience in N-11 countries is most affected by the C4 coded Supply Chain Visibility criterion and the C3 coded Corporate Governance criterion. This indicates that the highest difference in supply chain resilience indicators among N-11 countries occurs among these criteria.

In the second stage of the evaluation process, the EDAS method was used to rank N-11 countries according to their supply chain resilience performance. Firstly, in this context, average solutions for each criterion were obtained using

Table 3. MEREC Normalized Decision Matrix

N-11 Countries	C_1	C_2	C_3	C_4	C_5
Bangladesh	0,5288	0,7962	0,4871	0,3535	0,7064
Egypt	0,2779	0,6207	0,3557	0,3823	0,5412
Indonesia	0,3140	0,3985	0,3486	0,2154	0,3837
Iran	0,3387	0,9759	1,0000	0,3617	0,4750
Mexico	0,2816	0,6503	0,3498	0,2776	0,4196
Nigeria	1,0000	1,0000	0,3320	0,4039	0,6073
Pakistan	0,4474	0,6437	0,3318	1,0000	1,0000
Philippines	0,4146	0,4296	0,4742	0,2636	0,6617
South Korea	0,1967	0,2025	0,2758	0,1602	0,3327
Türkiye	0,2707	0,3800	0,3130	0,2269	0,3937
Vietnam	0,3286	0,3838	0,4903	0,1935	0,3831

Table 4. Performance Scores of Alternatives If Criteria Are Removed

N-11 Countries	C_1	C_2	C_3	C_4	C_5
Bangladesh	1,1482	1,1738	1,009	0,8847	1,1361
Egypt	1,3095	1,352	1,1965	1,2181	1,3159
Indonesia	1,5541	1,5642	1,5357	1,4264	1,5562
Iran	1,0175	1,0912	1,0994	0,6859	0,8144
Mexico	1,4555	1,4938	1,3439	1,2817	1,3903
Nigeria	1,255	1,255	0,8777	0,956	1,1016
Pakistan	0,7845	0,8172	0,4709	0,995	0,995
Philippines	1,2979	1,2998	1,3264	1,1569	1,4111
South Korea	1,7118	1,7129	1,7671	1,6697	1,7986
Türkiye	1,5624	1,5765	1,5356	1,4639	1,5838
Vietnam	1,5055	1,5124	1,565	1,3488	1,512

Table 5. Absolute Deviations and Weights of Criteria

Results	C_1	C_2	C_3	C_4	C_5
E_j	1,7196	1,4728	2,5945	3,2349	1,7067
w_j	0,1603	0,1373	0,2418	0,3015	0,1591

equation (9) based on the data presented in Table 2. Then, by applying equation (10) and equation (12), the positive distance matrix in Table 6 was obtained.

The values in Table 6 also indicate whether the performance scores of N-11 countries on the relevant criteria are above the average. Distance scores of countries with criterion performance below the average in the positive distance matrix take the value 0. In this context, Bangladesh is a country that falls below the average in all criteria among the N-11 countries.

The EDAS method ranks alternatives by considering both their positive and negative distances from the mean solution. In this regard, the negative distances of the alternatives to the mean solution were calculated using equations (11) and (13), and the negative distance matrix in Table 7 was obtained.

The next step of the evaluation process using the EDAS method is to calculate the weighted total distance scores. The weighted positive total distance values of the N-11 countries were calculated using equation (16), and the weighted negative total distance values were calculated using equation (17), considering the criteria weights obtained by the MEREC method. The obtained values were then normalized using equations (18) and (19), respectively. Finally, the N-11 countries were ranked using equation (20), and the application of the EDAS method was completed. The results obtained from these calculations and the ranking of the countries according to the EDAS method are presented in Table 8.

In the next phase of the evaluation process, N-11 countries' performance on supply chain resilience was analyzed using the MARCOS method. According to the solution steps of the MARCOS method, firstly, an expanded initial

Table 6. Positive Distance Matrix

N-11 Countries	C_1	C_2	C_3	C_4	C_5
Bangladesh	0,0000	0,0000	0,0000	0,0000	0,0000
Egypt	0,2126	0,0000	0,0817	0,0000	0,0000
Indonesia	0,0730	0,2003	0,1039	0,2914	0,2645
Iran	0,0000	0,0000	0,0000	0,0000	0,0215
Mexico	0,1967	0,0000	0,1000	0,0023	0,1562
Nigeria	0,0000	0,0000	0,1589	0,0000	0,0000
Pakistan	0,0000	0,0000	0,1597	0,0000	0,0000
Philippines	0,0000	0,1134	0,0000	0,0555	0,0000
South Korea	0,7126	1,3621	0,3954	0,7361	0,4582
Türkiye	0,2447	0,2588	0,2294	0,2258	0,2325
Vietnam	0,0255	0,2465	0,0000	0,4381	0,2664

Table 7. Negative Distance Matrix

N-11 Countries	C_1	C_2	C_3	C_4	C_5
Bangladesh	0,3629	0,3992	0,2101	0,2130	0,3132
Egypt	0,0000	0,2293	0,0000	0,2723	0,1035
Indonesia	0,0000	0,0000	0,0000	0,0000	0,0000
Iran	0,0051	0,5098	0,6152	0,2309	0,0000
Mexico	0,0000	0,2644	0,0000	0,0000	0,0000
Nigeria	0,6631	0,5216	0,0000	0,3112	0,2011
Pakistan	0,2469	0,2568	0,0000	0,7218	0,5148
Philippines	0,1872	0,0000	0,1885	0,0000	0,2667
South Korea	0,0000	0,0000	0,0000	0,0000	0,0000
Türkiye	0,0000	0,0000	0,0000	0,0000	0,0000
Vietnam	0,0000	0,0000	0,2151	0,0000	0,0000

Table 8. Scores and Ranks of N-11 Countries Obtained by the EDAS Method

N-11 Countries	SP_i	SN_i	NSP_i	NSN_i	AS_i	Rank
Bangladesh	0,0000	0,2778	0,0000	0,2579	0,1290	8
Egypt	0,0538	0,1301	0,0778	0,6526	0,3652	7
Indonesia	0,1943	0,0000	0,2809	1,0000	0,6404	3
Iran	0,0034	0,2892	0,0049	0,2275	0,1162	10
Mexico	0,0813	0,0363	0,1175	0,9031	0,5103	5
Nigeria	0,0384	0,3037	0,0555	0,1887	0,1221	9
Pakistan	0,0386	0,3744	0,0558	0,0000	0,0279	11
Philippines	0,0323	0,1180	0,0467	0,6847	0,3657	6
South Korea	0,6917	0,0000	1,0000	1,0000	1,0000	1
Türkiye	0,2353	0,0000	0,3402	1,0000	0,6701	2
Vietnam	0,2124	0,0520	0,3071	0,8610	0,5841	4

Table 9. Initial Decision-Making Matrix

N-11 Countries	C_1	C_2	C_3	C_4	C_5
AAI	18,7105	12,0977	22,8980	12,1302	26,3927
Bangladesh	35,3797	15,1938	47,0075	34,3163	37,3637
Egypt	67,3353	19,4906	64,3662	31,728	48,7696
Indonesia	59,5835	30,3565	65,6898	56,3081	68,7901
Iran	55,2474	12,3961	22,898	33,535	55,5691
Mexico	66,4529	18,6043	65,4598	43,7028	62,894
Nigeria	18,7105	12,0977	68,9604	30,0341	43,4584
Pakistan	41,8203	18,7951	69,0096	12,1302	26,3927
Philippines	45,1319	28,1575	48,2889	46,0242	39,8887
South Korea	95,1011	59,7367	83,0357	75,7002	79,3242
Türkiye	69,1152	31,8352	73,1571	53,4494	67,0442
Vietnam	56,9438	31,5238	46,7067	62,7041	68,8932
AI	95,1011	59,7367	83,0357	75,7002	79,3242

decision-making matrix was created by using equation (22) and equation (23), considering the data in Table 2. The resulting matrix is presented in Table 9.

In the next step of the evaluation process using the MARCOS method, the matrix in Table 9 was normalized using equality (25), and a weighted normalized decision

Table 10. N-11 Countries Scores and Ranks for the MARCOS Method

N-11 Countries	S_i	K_i^-	K_i^+	$f(K_i^-)$	$f(K_i^+)$	$f(K_i)$	Rank
Bangladesh	0,4431	1,9495	0,4431	0,1852	0,8148	1,3518	9
Egypt	0,5699	2,5077	0,5699	0,1852	0,8148	2,6683	3
Indonesia	0,7237	3,1845	0,7237	0,1852	0,8148	5,6173	7
Iran	0,4333	1,9066	0,4333	0,1852	0,8148	1,2770	1
Mexico	0,6456	2,8407	0,6456	0,1852	0,8148	3,8695	10
Nigeria	0,4670	2,0546	0,4670	0,1852	0,8148	1,5487	5
Pakistan	0,4159	1,8300	0,4159	0,1852	0,8148	1,1513	6
Philippines	0,5447	2,3968	0,5447	0,1852	0,8148	2,3476	8
South Korea	1,0000	4,4001	1,0000	0,1852	0,8148	23,7607	11
Türkiye	0,7501	3,3003	0,7501	0,1852	0,8148	6,3662	2
Vietnam	0,6924	3,0465	0,6924	0,1852	0,8148	4,8394	4

matrix was then created using equality (26). The distances of the N-11 countries from the anti-ideal solution were found using equation (27), and their distances from the ideal solution were calculated using equation (28). Finally, using equation (30), the values of the countries' utility functions were determined, and their rankings were established. The results of the calculations and the rankings of the N-11 countries according to the MARCOS method are presented in Table 10.

In the fourth stage of the evaluation process, the performance of the N-11 countries regarding supply chain resilience was analyzed using the WASPAS method. Firstly, a decision matrix was created by considering the data in Table 2, and then it was normalized using the matrix formed by equation (34). Next, the evaluation scores of the N-11 countries were calculated using the weighted sum and weighted multiplication methods, based on equations (37) and (38). Finally, since these two evaluation methods were deemed equally important, the weighted common criterion values of the N-11 countries were calculated using equation (39), and the countries were ranked based on the obtained values. The results of the calculations and the rankings of the N-11 countries are presented in Table 11.

At the last stage of the evaluation process, the rankings of N-11 countries obtained by the EDAS, MARCOS and WASPAS method were combined with the BORDA method to obtain the final ranking in Table 12.

As seen in Table 12, South Korea ranked as the best N-11 country in terms of supply chain resilience within the scope of the research, followed by Türkiye and Indonesia, respectively. Furthermore, Pakistan, Iran, and Bangladesh ranked as the countries with the lowest supply chain resilience among the N-11 countries.

5. CONCLUSION

Supply chains are organizations in which many actors with different positions and characteristics have to work together. This situation causes supply chains to take on a complex structure and face many risk factors. In addition, a malfunction that may occur at any point in the chain due to the interdependence of the chain actors can spread to the entire chain and cause devastating results. For this reason, it is of

Table 11. N-11 Countries Scores and Ranks for the WASPAS Method

N-11 Countries	$Q_i^{(1)}$	$Q_i^{(2)}$	Q_i	Rank
Bangladesh	0,4431	0,1210	0,2820	9
Egypt	0,5699	0,1526	0,3612	6
Indonesia	0,7237	0,2006	0,4622	3
Iran	0,4333	0,1123	0,2728	10
Mexico	0,6456	0,1742	0,4099	5
Nigeria	0,4670	0,1143	0,2906	8
Pakistan	0,4159	0,0971	0,2565	11
Philippines	0,5447	0,1521	0,3484	7
South Korea	1,0000	0,2809	0,6404	1
Türkiye	0,7501	0,2081	0,4791	2
Vietnam	0,6924	0,1905	0,4414	4

Table 12. N-11 Countries Final Ranks

N-11 Countries	Score	Rank
Bangladesh	7	9
Egypt	14	6
Indonesia	24	3
Iran	3	10
Mexico	18	5
Nigeria	8	8
Pakistan	0	11
Philippines	13	7
South Korea	30	1
Türkiye	27	2
Vietnam	21	4

great importance to maintain uninterrupted flow of semi-finished products and finished products in supply chains.

The continuity of the semi-finished and finished product flow in the supply chains, despite all the uncertainties and disruptions, depends on the circularity of the supply chain. Making a supply chain resilient and sustaining this resilience require a combination of strategic practices such as shortening lead times, establishing advanced cooperation with flexible suppliers, closely monitoring the flow in the chain, and improving the integration between supply chain actors. Although these practices have the effect of increasing supply chain resilience, the dynamics of the region where supply chain activities are carried out play an active role in increasing resilience to a high level and making it permanent. Therefore, supply chain managers should closely monitor the dynamics of the regions where the chain spans.

Supply chain resilience is of critical importance not only for chain actors but also for national economies. Non-resistive supply chains can trigger major disruptions because of unexpected disruptions, causing loss of workforce and economic problems. In addition, countries with non-resilient supply chain networks have difficulties in attracting investors. Therefore, just like supply chain managers, policy makers should monitor the resilience of the supply chains in their countries and even develop policies and practices to increase supply chain resilience.

Although supply chain resilience is a crucial issue for both chain actors and policymakers, it is often dealt with on an enterprise level, and its national aspect is overlooked. The literature review reveals that scientific studies are mostly focused on specific businesses or sectors and explore the factors that affect supply chain resilience. Therefore, in this study, supply chain resilience has been tried to contribute to the literature by considering country-based. In this context, supply chain resilience in N-11 countries, which have the potential to be the supply centers of the future due to their resources and socioeconomic characteristics, has been examined.

In this study, the MEREC, EDAS, MARCOS, and WASPAS methods were integrated and used based on the Global Resilience Index data published by FM Global. Firstly, the MEREC method was used to determine the weights of the indicators that affect the supply chain resilience of the countries. Then, the EDAS, MARCOS, and WASPAS methods were used separately to determine the rankings of the countries based on their supply chain resilience. Finally, the BORDA counting method was used to combine the final rankings and form the overall rankings of the N-11 countries. This approach attempted to fill the gap in the literature on supply chain resilience by considering it on a country basis, and also aimed to enrich the decision-making literature by integrating four different MCDM methods.

The calculations carried out to determine the indicator weights with the MEREC method revealed that the Supply Chain Visibility and Corporate Governance indicators are the most significant factors affecting supply chain resilience in N-11 countries. These findings suggest that the indicators identified by Jafarnejad et al. (2019) can also be utilized to evaluate national supply chain resilience. Moreover, it is clear that investing in supply chain visibility and corporate governance will lead to significant improvements in supply chain resilience. Whence, organizations with supply chain operations in N-11 countries are expected to become more competitive if they adopt institutionalization approaches and closely monitor supply chain flows. However, it should not be overlooked that spending excessively to increase supply chain resilience may cause harm instead of benefit. Therefore, it is recommended to maintain a balance in resilience, as advocated by Zhang et al (2021). In this regard, it is thought that state supports will be an important factor in establishing this balance, as in the suggestions of Das et al. (2022).

Similar results were obtained in the assessments of supply chain resilience in N-11 countries using the EDAS, MARCOS, and WASPAS methods. South Korea ranked first, followed by Türkiye in second place, and Indonesia in third place in each of the calculations made with the three methods. Additionally, Pakistan and Iran ranked last in the findings of the three methods. Although there were minor ranking differences in other countries, the fact that the methods with different calculation algorithms mostly give similar results indicates the high reliability of the evaluation. However, due to slight differences in the three different methods, the results of the ranking were combined with the BORDA counting method to create a more reliable final ranking. Considering the final ranks, it can be understood that South Korea and Türkiye have a very good position among the N-11 countries in terms of supply chain durability. This situation is thought to allow Türkiye to host more supply chain operations in the future. Nevertheless, it is crucial for Türkiye to continue to develop policies and practices to protect this potential, as the economic conjuncture is constantly changing, and the world is witnessing events that may cause new disruptions every day in an increasingly globalized and intensifying competitive environment. Increasing transportation costs cause supply chains to be fragmented and organized with local sub-chains, while scarce resources force supply chains to work with more efficient operations. Therefore, providing and maintaining resilience in supply chains is becoming increasingly difficult and requires additional applications. This situation demonstrates similarities at both the national and business levels. As a matter of fact, Ponomarov and Holcomb (2009) emphasized in their research on businesses that it is necessary to continuously develop talents to make the supply chain more resilient. For this reason, policymakers should continue to provide the necessary infrastructure and technology for supply chains to become more durable throughout the country and develop policies that will make their supply chains more functional.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

The study's findings are limited to the N-11 countries and may not necessarily be applicable to other countries or regions. Therefore, if the number of countries studied changes, different results may be obtained. Nevertheless, the methodology used in this study can be applied to other countries or regions to evaluate their supply chain resilience.

The most important limitation of the study is the data used in the evaluation. Because the Global Resilience Index data published by FM Global, which is the only data source on national supply chain resilience, was used in this study. This limitation can be removed with the measurement tools to be developed to measure the resilience of the National Supply Chain. Another limitation of the research is the solution algorithms of the methods used. Although five different methods were used together in the evaluation process to increase reliability, the algorithms of the methods have limitations. These limitations can be reduced by using new methods to be developed.

Supply chain resilience of different countries and country groups can be addressed in future research, and different methods can be used in evaluation processes. In addition, indicators for determining supply chain resilience can be developed, empirical studies can be carried out, and the impact of supply chain resilience on national economies can be examined.

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