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Analysis of the Foreign Trade Performance of Transportation Types Using Multi-Criteria Decision-Making Methods: The Case of Türkiye[1]

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Taşımacılık Türlerinin Dış Ticaret Performansının Çok Kriterli Karar Verme Yöntemleri ile Analizi: Türkiye Örneği[2]

Abstract

This study examines the foreign trade performance of different modes of transport in Türkiye over the period 2014-2023, employing Multi-Criteria Decision-Making methods, specifically the LOPCOW and CoCoSo techniques. The results of the LOPCOW analysis indicate that the foreign trade balance is the most important criterion across all transportation modes. The CoCoSo analysis suggests that the best-performing years are 2022 for road and maritime transportation, 2023 for railway transportation, 2021 for air and overall transportation, and 2017 for other transportation types.

Keywords : Foreign Trade, Transportation Types, LOPCOW, CoCoSo, Performance Analysis.

JEL Classification Codes : L90, L91.

Öz

Bu araştırmada; Türkiye'nin 2014-2023 yılları arasındaki 10 yıllık dönemi kapsayan taşıma türlerine göre dış ticaret performansı Çok Kriterli Karar Verme Yöntemlerinden LOPCOW ve CoCoSo Teknikleri ile analiz edilmiştir. LOPCOW Analizi sonucunda dış ticaret dengesi, tüm taşıma türlerinde en yüksek önem derecesine sahip kriter olarak belirlenmiştir. CoCoSo Analizi sonucunda ise karayolu taşımacılığı ve denizyolu taşımacılığında 2022 yılı, demiryolu taşımacılığında 2023 yılı, havayolu taşımacılığı ve toplam taşıma türlerinde 2021 yılı ve diğer taşıma türleri taşımacılığında 2017 yılı en iyi performansa sahip yıllar olarak tespit edilmiştir.

Anahtar Sözcükler : Dış Ticaret, Taşımacılık Türleri, LOPCOW, CoCoSo, Performans Analizi.

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[2] *Bu makale, Kafkas Üniversitesi Sosyal Bilimler Enstitüsü Uluslararası Ticaret ve Lojistik Bölümü'nde Doç. Dr. Ceyda Yerdelen-Kaygın danışmanlığında Süleyman Evelek tarafından 2024 yılında tamamlanan "Taşımacılık Türlerine Göre Dış Ticaret Performansı: Türkiye Örneği" başlıklı yüksek lisans tezinden türetilmiştir.*

1. Introduction

Since the dawn of humanity, the concept of trade has served the demands of individuals (Aydın, 2023: 2). In ancient times, trade took place along the Silk Road and the Spice Route, acting as vital arteries in a world where commercial exchanges extended over thousands of miles (Usul, 2023: 1784). In the past, needs were met through barter, whereas today the use of digital currency is seen as an indicator of development and change in trade (Yücekaya & Özcimbit, 2023: 330). It is well known that the invention of the steam engine accelerated both production and transportation, enabling the movement of larger loads across greater distances (Güdek, 2023: 1136). This development has made it easier and faster to transport larger loads, reinforcing the idea that trade and transportation are closely connected.

The concept of foreign trade originated with the start of commerce not only between nations but also across entire continents. Foreign trade is usually seen as the business of selling domestically produced goods and services in excess of domestic demand to foreign consumers, or of acquiring goods and services from abroad that are not produced locally or are produced only in limited quantities (Öztürk, 2003: 121). Put simply, foreign trade involves the buying and selling of goods and services between two or more countries (Batmaz, 2023: 12). All activities related to importing and exporting goods are part of foreign trade (Özmen, 2014: 46). There are many ways foreign trade benefits the national economy. It provides the government with a significant source of revenue and helps address market inefficiencies. Trading with other nations clearly promotes international development and offers numerous social benefits. Additionally, it enhances diplomatic relations with other countries. Therefore, plans for sustainable economic growth should be grounded in the foundation that foreign trade provides.

The concepts of foreign trade and logistics are mutually nourishing and complementary systems that, when integrated, form a well-functioning foreign trade structure. Today, the rapid pace of technological advancement, the growing global population, and the rise of new urban areas demand that commercial and transportation activities be conducted more efficiently (Demir & Tanyıldızı, 2017: 96-97).

The main modes of transport that shape efficient international trade are road, maritime, air, and rail. This study concentrates on the variables of Türkiye's foreign trade. The dataset spans 2014 to 2023 and includes components such as exports and imports, foreign trade balances, trade volumes, and coverage ratios relevant to Türkiye's foreign trade. The research utilises the LOPCOW and CoCoSo techniques. The originality of this study lies in the integrated approach to the dataset and the application of recently developed analytical techniques, thereby enriching the literature. Analysing how Türkiye's exports and imports vary across modes of transportation over time can assist decision-makers and policymakers in devising more effective strategic plans for foreign trade and logistics from multiple perspectives. They can also monitor progress toward the Sustainable Development Goals and determine the most effective ways to support economic growth.

2. Literature Review

Today's global economy relies on two key and inseparable elements: foreign trade and logistics. Halaszovich and Kinra (2020) asserted that transportation systems positively influence trade and foreign direct investment, with logistics being essential to economic growth, especially in these areas. In their 2021 study, Ma et al. found that logistics infrastructure not only supports the formation of international trade but also acts as a regional equaliser, reducing development disparities across regions within a country. As Górecka et al. (2021) pointed out, the better logistics perform, the more energy trade is facilitated; improved logistics also contribute to a more secure energy supply, aiding the transition to domestic and renewable resources. The work of Song and Lee (2022) showed that growth in logistics services directly impacts the expansion of international trade, and that a country's logistics development is a necessary condition for increasing its trade volume with other nations. Zhao et al. (2023) stated that developing the logistics sector can not only boost trade volume but also improve a country's position within the global value chain. Overall, these findings demonstrate that adopting a comprehensive, well-ordered system of foreign trade and logistics is much more likely to promote the sustainable development of international trade.

2.1. Literature Review on International Trade

The literature review shows that most research on foreign trade focuses on the relationship between trade and economic growth. Helpman (1999) noted that factors such as economies of scale and product differentiation are important in determining international trade, emphasising that theories of international trade may need further development. The research by Daudin et al. (2006) sheds light on how vertical transformation in international trade could promote economic growth, arguing that the economy requires further structural changes to achieve a modest increase in the ratio of foreign trade to GDP. Çolpan-Nart (2010) found that the Customs Union increased the total trade volume between countries. Soukiazis and Antunes (2011) and Purnama and Yao (2019) highlighted the importance of external trade for regional growth.

Foreign direct capital is one of the most crucial building blocks of foreign trade growth; it enhances export potential, thereby enabling a country to integrate more effectively into the global economy. In a 2009 study, Altıntaş found that foreign direct capital not only increased exports but also imports. An alternative perspective is offered by Esener & Yereli (2025), who argued that it was not foreign direct investment that influenced a country's economic growth, but rather a country's economic growth that attracted foreign direct investment.

Genuinely sustainable foreign trade policies promote long-term growth, enabling nations to become increasingly competitive in the global economy. According to Sezgin (2009), foreign trade growth during specific periods was much faster than gross national product growth, and foreign trade had a very significant and influential impact in those years.

Şerefli (2016) identified a causal relationship between foreign trade and economic growth. Aytaç & Akduğan (2012) found a relationship between imports, exports, and GDP. They discovered that exports increased GDP. Kızıldere (2020) suggested an alternative sequence among these variables, indicating that causality runs from economic growth to imports and from exports to imports. The study also noted that economic growth was associated with higher exports. Although Ersungur and Doru (2014) demonstrated a bidirectional relationship between foreign trade and economic development, Korkmaz and Aydın (2015) further revealed a bidirectional relationship between imports and economic growth. According to Akcan and Metin (2018), exports and imports drove economic growth before the global crisis, whereas in the post-crisis period, imports had no significant causal effect on economic growth. Ata and Eren (2017) and Ganiev (2015) argued that the impact of imports and exports on economic growth was largely positive, whereas Madzínová (2011) and Purnama & Yao (2019) identified a long-term relationship between foreign trade and economic growth, with foreign trade having notable effects. These findings suggest that foreign trade, including both exports and imports, positively affects economic growth. However, the outcomes are not entirely consistent. Whether foreign trade benefits a particular country at a given time depends on the types of traded goods, the mode of trade, and the analytical methods employed.

2.2. Literature Review on Logistics

The body of research concerning transportation modes tends to focus on road transport. Within that area, it primarily emphasises factors such as economic growth, the competitive positioning of road transport, and passenger preferences when choosing to travel by road. Although Özer et al. (2006) found that demographic and socioeconomic factors played a decisive role in determining passenger preferences, Ivanova and Masarova (2013) stated that road infrastructure had the "broadest and heaviest impact" of any factor on an economy's growth and competitiveness. By establishing a stronger link between sectoral development and economic growth, Macit (2020) argued that road freight transport was significantly associated with trade and that this relationship was also reflected in GDP.

Navas-Anguita et al. (2019) and Merkisz-Guranowska et al. (2013) highlighted the need to assess road transportation not only from an economic perspective but also with respect to environmental and energy considerations. Kiziltan et al. (2023) indicated that renewing the vehicle fleet would have produced several positive outcomes beneficial for the economy, public health, and the environment.

Various aspects of railway transportation, such as sustainable energy use, economic growth, and efficiency, are examined in the literature. Emirkadı & Balcı (2023) provided substantial evidence linking road and railway transport to economic growth. Kabasakal & Solak (2011) discussed the efficiency of railway transport and ways to improve it. Nazir (2019) observed the technical and economic feasibility of meeting railways' energy needs with solar power, highlighting that the use of renewable energy significantly supports

sustainability. Bayane et al. (2020) stated that developing the railway system would have stimulated long-term economic growth and trade.

Research on air transportation indicates that it plays a strategic and increasingly important role in economic growth, competition, and job creation. Kiracı (2018) found a strong causality between airline demand and economic growth. Kundak & Aktop (2018) noted that air transportation offers significant opportunities for employment and economic development. Eren et al. (2020) demonstrated that air transportation is strongly associated with economic growth. Additionally, Altuntaş & Kılıç (2021) found that air passenger traffic has a strong bilateral causality with economic growth. According to Fu et al. (2010), liberalisation policies have boosted competition within the aviation industry. Vennix (2017) states that the air transportation sector has had a positive economic impact. Heshmati et al. (2018) aimed, however, to examine airline efficiency.

In maritime transportation, factors such as economic growth, sustainability, efficiency, and safety may appear to be at odds. Fratila et al. (2021) found that maritime transportation is positively associated with economic growth, whereas Jin et al. (2022) found that optimising maritime transportation systems is an effective means of enhancing sustainability and efficiency. Psaraftis & Kontovas (2010) highlighted the importance of reducing greenhouse gas emissions in marine transportation for environmental benefits. Rawson & Brito (2023) found that machine learning and big data techniques in the maritime sector yield more reliable estimates of accident probability and severity.

In the literature, transportation modes are predominantly treated as single modalities (e.g., road, air, and sea) in relation to concepts such as foreign trade, economic growth, the environment, and sustainability. This study addresses a gap in the literature by comprehensively examining all transportation modes, both individually and collectively, and integrating these analyses to highlight how this research differs from prior work in the field. Furthermore, it has been identified that analyses such as Panel Data Analysis, Granger Causality Test, VAR Analysis, Johansen Cointegration Test, and ARDL Bounds Test are commonly employed in research concerning foreign trade and logistics topics (Altıntaş, 2009; Soukiazis & Antunes, 2011; Aytaç & Akduğan, 2012; Ganiev, 2015; Boakye & Gyamfi, 2017; Purnama & Yao, 2019; Fratila et al., 2021; Esener & Yereli, 2025). Most existing studies aim to determine the directionality of the variables examined. The application of MCDM methods, recently introduced to this area, offers a strong analytical tool based on quantitative weighting for assessing the foreign trade performance of transportation modes. Consequently, identifying the relative importance of variables and their weights in the decision-making process distinguishes this research from other works in the literature.

3. Methodology

The decade-long foreign trade performance of Türkiye has been evaluated across transportation modes using MCDM methods. The research is divided into several sections.

It begins by stating the study's purpose and scope, then explains why the research is important. This is followed by a discussion of the study's limitations. Next, it describes the data and variables employed. Afterwards, the methodology is outlined, and finally, the research findings are presented.

3.1. Purpose and Scope of the Research

This study aims to achieve two objectives: first, to analyse ten years of Türkiye's foreign trade data by mode of transportation; and second, to comprehensively evaluate the data. The techniques employed for this MCDM analysis are LOPCOW and CoCoSo.

Research Questions:

1. To determine the years in which Türkiye experienced the best and worst foreign trade performance in road transportation from 2014 to 2023.
2. To identify the years in which Türkiye experienced the best and worst foreign trade performance in railway transportation from 2014 to 2023.
3. To determine the years in which Türkiye experienced the best and worst foreign trade performance in air transportation between 2014 and 2023.
4. To identify the years in which Türkiye experienced the best and worst foreign trade performance in maritime transportation between 2014 and 2023.
5. To identify the years in which Türkiye experienced its best and worst foreign trade performance in other transportation types between 2014 and 2023.
6. To identify the years in which Türkiye experienced the best and worst overall foreign trade performance across all transportation types from 2014 to 2023.

Performance is essential not only for achieving set objectives and maintaining success (Karaman, 2009: 411) but also for monitoring failures, understanding their causes, and implementing necessary measures (Atukalp, 2019: 216). High performance success confers a competitive advantage both in national and international markets (Karcıoğlu et al., 2020: 361). Therefore, this research is based on the hypothesis that assessing foreign trade performance can clearly highlight a country's strengths and weaknesses and serve as an effective method for comparing its processes of change and development. Analysing foreign trade performance annually by transportation types is believed to offer a preliminary opportunity to identify factors that enhance or hinder success at the micro level for companies and at the macro level for countries.

3.2. Importance of the Research

This research is necessary because it examines key concepts in international trade and transportation that could promote sustainable economic development and growth.

3.3. Limitations of the Research

This research is limited by the dataset used, the variables considered, the time period, and the analytical methods applied. The dataset, variables, and methods were selected within a specific timeframe and scope in accordance with the study's objectives. The study's limitations include a lack of a detailed examination of external shocks, such as the pandemic, and of regional differences in transportation modes.

3.4. Data and Variables Used in the Research

To construct the dataset, the foreign trade performance of Türkiye's various transportation modalities was first evaluated. Annual performance assessments were performed using foreign trade data (exports, imports, trade balance, trade volume, and trade coverage ratio). Consequently, actual export and import data, sourced from the Turkish Statistical Institute (TSI), were used to calculate the score points. The study employed an extensive dataset, which, because the TSI data are pre-audited, presented in standard formats, and show no apparent quality concerns, can be used without modification or the addition of any missing components.

3.5. Methodology of the Research

The multitude of techniques embedded within MCDM can be seen as a spectrum centred around the core process of modelling maximising utility (Kocadüz, 2023: 37). They are practical problem-solving tools and are also suitable for identifying the most favourable alternative within a specific objective framework using several techniques to achieve that result (Süzülmüş & Polat, 2022: 26; Mercan, 2023: 6-8). MCDM facilitates the pursuit of the best decision among the given alternatives and arranges them according to predetermined goals (Akginel, 2019: 24). In this investigation, the LOPCOW method was utilised for criteria weighting and the CoCoSo method for ranking the alternatives.

3.5.1. LOPCOW (Logarithmic Percentage Change-driven Objective Weighting) Method

The formulas used in the application phase of the method include the following variables (Ecer & Pamucar, 2022: 4-6; Lukic, 2023: 107-112; Ayçin, 2023: 480-481; Dhruva et al., 2024: 75-82; Rong et al., 2024: 23-27; Simic et al., 2023: 5-8). Developed by Ecer and Pamucar in 2022, the LOPCOW method has a distinctive way of assigning weights to the criteria being assessed (Ecer & Pamucar, 2022: 3; Kahreman, 2023: 1). Unlike some other weighting methods, LOPCOW employs a combination of the standard deviation and the percentage values of the criteria to produce objective criterion weights (Gülcemal & İzci, 2024: 122). The LOPCOW method was chosen for application in this study due to its ability to handle logarithmic change rates, its proven track record of generating weights that give more importance to criteria showing greater variation, and, perhaps most notably, its capacity to produce weights without bias from the decision-maker (Rong et al., 2024: 4).

Stages of the LOPCOW Method

The LOPCOW Method comprises four stages:

Stage 1: Formation of the Initial Decision Matrix

The decision matrix, with *m* alternatives and *n* criteria, is generated using Formula (1).

$$BKM = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \end{matrix} \quad (1)$$

Stage 2: Normalisation of the Initial Decision Matrix

The elements in the decision matrix were normalised by assigning values within the range [0,1], as shown in Formula (2).

$$R = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \end{matrix} \quad (2)$$

The criteria for benefit maximisation and cost minimisation were determined using Formulas (3) and (4), respectively.

$$r_{ij} = \frac{X_{ij} - min\, X_{ij}}{max\, X_{ij} - min\, X_{ij}} \quad (3)$$

$$r_{ij} = \frac{max\, X_{ij} - X_{ij}}{max\, X_{ij} - min\, X_{ij}} \quad (4)$$

Stage 3: Calculation of Percentage Values for Each Criterion (PV_{ij})

The mean square values of all percentages for each criterion, calculated using Formula (5), are determined to fill gaps caused by data deficiencies.

$$PV_{ij} = \left| \ln \left(\frac{\sqrt{\frac{\sum_{i=1}^{m} r_{ij}^2}{m}}}{\sigma} \right) . \quad 100 \right| \quad (5)$$

In the formula, the standard deviation is represented by σ, while m indicates the decision alternative.

Stage 4: Obtaining Objective Significance Weights for the Criteria

In the final stage, the objective weights are determined using the PV_{ij} values identified in the earlier stages, following the method outlined in Formula (6).

$$w_j = \frac{PV_{ij}}{\sum_{i=1}^{n} PV_{ij}} \tag{6}$$

3.5.2. CoCoSo (Combined Compromise Solution) Method

The CoCoSo Method conducts a comprehensive analysis of potential compromise solutions for decision-makers (Popović, 2021: 81). It outperforms other integrated and compromise methods in resolving differences among decision-makers and more effectively identifies, in terms of resolution, the compromise solutions needed when making overall judgments (Wang et al., 2022: 7; Chen et al., 2022: 2-4). It combines the advantages of arithmetic means through a hybrid approach (Lai et al., 2020: 414-415) and merges simple additive weighting with an exponential multiplication model. The CoCoSo method is preferred for its innovative integration of multiple aggregation strategies, making it well-suited to translating preferences from ranking results. This is especially useful when conducting a holistic analysis that combines various methods. CoCoSo's capacity to rank alternatives with nuance makes it particularly valuable for decision-making scenarios. Its logical robustness in supporting decision-makers also makes it highly appropriate for analysis (Khan & Haleem, 2021: 358-359).

The variables included in the formulas used during the application phase of the method are as follows (Yazdani et al., 2019: 2507; Ayçin, 2023: 434-436; Wang et al., 2022: 7-8).

Stages of the CoCoSo Method

The CoCoSo Method comprises five stages:

Stage 1: Formation of the Decision Matrix

The decision matrix, comprising *m* alternatives and *n* criteria, is computed using Formula (7) and is presented below.

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \end{array} \tag{7}$$

In this formula, the x_{ij} values denote the j-th criterion related to the i-th alternative.

Stage 2: Normalisation of the Decision Matrix

The normalisation process for the elements in the decision matrix is performed by mapping values to [0,1], yielding the arrangement shown in Formula (8).

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \end{array} \tag{8}$$

In the normalisation process, maximisation criteria are calculated using Formula (9), while minimisation criteria are addressed using Formula (10).

$$r_{ij} = \frac{X_{ij} - min\ X_{ij}}{max\ X_{ij} - min\ X_{ij}} \tag{9}$$

$$r_{ij} = \frac{max\ X_{ij} - X_{ij}}{max\ X_{ij} - min\ X_{ij}} \tag{10}$$

Stage 3: Calculation of (S_i) and (P_i) Values

The total weighted comparable index value S_i and the power-weighted comparability index value P_i are calculated as shown in Formulas (11) and (12), respectively.

$$S_i = \sum_{J=1}^{n} \left(w_j r_{ij}\right) \tag{11}$$

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j} \tag{12}$$

Additionally, the w_j value in this formula indicates the degree of significance weight of the j-th criterion.

Stage 4: Calculation of Relative Performance of Alternatives

The values of the options at this stage are determined using three distinct evaluation strategies outlined in Formulas (13-15).

$$k_{ia} \frac{P_i + S_i}{\sum_{i=1}^{m} (P_i + S_i)} \tag{13}$$

$$k_{ib} = \frac{S_i}{\underset{i}{min} S_i} + \frac{P_i}{\underset{i}{min} P_i} \tag{14}$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{\lambda \underset{i}{max} S_i + (1-\lambda) \underset{i}{max} P_i} \tag{15}$$

Formula (13) calculates the arithmetic mean of the WSM and WPM values, while Formula (14) sums the relative values of WSM and WPM compared to the best, and Formula (15) is used to determine the balanced optimisation of WSM and WPM model scores.

Although the literature generally adopts the value of "ƛ" as 0.50, a different ƛ parameter may be chosen by the decision-maker.

Stage 5: Ranking of Alternatives

In the final stage, ranking is conducted using Formula (16), and based on the results, the k_i criteria are ordered from highest to lowest, with the highest value corresponding to the best alternative.

$$k_i = (k_{ia} + k_{ib} + k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia}k_{ib}k_{ic}) \quad (16)$$

4. Findings of the Research

The research findings are presented under two headings: the LOPCOW Method and the CoCoSo Method.

4.1. Findings of the LOPCOW Method

The LOPCOW Method was employed to analyse Türkiye's ten-year foreign trade data by transportation mode, with criterion weights assigned to road, railway, air, maritime, and other modes, as well as to the overall transportation types. The results are presented in tabular form, with the steps of the LOPCOW analysis for road transportation shown in Tables 1, 2, 3, and 4. The objective significance weights for the foreign trade performance criteria for railway, air, maritime, other transportation types, and the total of transportation types are presented in Table 5.

The stages for determining the criterion weights for Türkiye's ten-year foreign trade data related to road transportation, using the LOPCOW Method, are summarised in the tables below. Foreign trade data on road transportation was used to build the decision matrix, as shown in Table 1, employing Formula (1).

Table: 1
Road Transportation Decision Matrix

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**
2023	83066065.92	66942046.74	16124019.17	150008112.7	124.0865345
2022	78837774.67	59447024.84	19390749.82	138284799.5	132.618537
2021	68749375.68	48896681.49	19852694.19	117646057.2	140.601312
2020	53127587.69	41883476.8	11244110.88	95011064.49	126.8461736
2019	54461859.56	37177011.92	17284847.65	91638871.48	146.4933752
2018	52222467.59	39129379.96	13093087.63	91351847.56	133.4610148
2017	50988407.8	40374083.04	10614324.76	91362490.85	126.2899463
2016	49537436.35	36716500.27	12820936.08	86253936.62	134.9187313
2015	51946112.73	37840931.75	14105180.98	89787044.48	137.2749304
2014	61133175.85	40577283.08	20555892.78	101710458.9	150.6586228

The import and export data by year are shown in Table 1. The data on foreign trade performance should be as focused as possible. The normalisation matrix for road

transportation has been calculated using Formula (2) and Formula (3) and is presented in Table 2.

Table: 2
Road Transportation Normalised Decision Matrix

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**
2023	1.0000	1.0000	0.5542	1.0000	0.0000
2022	0.8739	0.7520	0.8828	0.8161	0.3211
2021	0.5730	0.4030	0.9293	0.4924	0.6215
2020	0.1071	0.1709	0.0633	0.1374	0.1039
2019	0.1469	0.0152	0.6710	0.0845	0.8432
2018	0.0801	0.0798	0.2493	0.0800	0.3528
2017	0.0433	0.1210	0.0000	0.0801	0.0829
2016	0.0000	0.0000	0.2220	0.0000	0.4077
2015	0.0718	0.0372	0.3511	0.0554	0.4963
2014	0.3458	0.1277	1.0000	0.2424	1.0000

All criteria have been calculated as percentage values using Formula (5). To perform this calculation, the squares of all values in the normalised matrix were taken, and the PV_{ij} value was computed. The calculated PV_{ij} values are presented in Table 3.

Table: 3
Road Transportation PV_{ij} Values

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**
2023	1.0000	1.0000	0.3071	1.0000	0.0000
2022	0.7637	0.5655	0.7793	0.6660	0.1031
2021	0.3283	0.1624	0.8635	0.2425	0.3863
2020	0.0115	0.0292	0.0040	0.0189	0.0108
2019	0.0216	0.0002	0.4502	0.0071	0.7111
2018	0.0064	0.0064	0.0622	0.0064	0.1245
2017	0.0019	0.0146	0.0000	0.0064	0.0069
2016	0.0000	0.0000	0.0493	0.0000	0.1662
2015	0.0052	0.0014	0.1233	0.0031	0.2463
2014	0.1196	0.0163	1.0000	0.0588	1.0000
PV_{ij}	1.0000	1.0000	0.3071	1.0000	0.0000

In the final stage, the objective significance weights of the criteria were calculated using Formula (6), and the resulting values are shown in Table 4.

Table: 4
Objective Significance Weights of Road Transportation Criteria

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**
w_j	0.1552	0.1248	0.2954	0.1438	0.2808

According to the LOPCOW Analysis, the most significant criterion for assigning weights to road transportation factors was the foreign trade balance, which accounted for 29.54%. The relative weights of the requirements are as follows: trade coverage ratio (28.08%), exports (15.52%), trade volume (14.38%), and imports (12.48%). The weights of the foreign trade performance criteria derived from the LOPCOW Analysis are collectively

presented in Table 5, covering road, railway, air, maritime, other transportation modes, and the overall total.

Table: 5
Foreign Trade Performance Criteria: Objective Significance Weights of Transportation Types

Criteria w_j Values	Max Export	Max Import	Max Foreign Trade Balance	Max Foreign Trade Volume	Max Foreign Trade Coverage Ratio
Road Transportation	0.1552	0.1248	0.2954	0.1438	0.2808
Railway Transportation	0.1294	0.1319	0.3191	0.1268	0.2929
Air Transportation	0.1862	0.1719	0.2683	0.1195	0.2541
Maritime Transportation	0.1939	0.1736	0.2386	0.1562	0.2377
Other Transportation Types	0.1728	0.1206	0.4055	0.1267	0.1744
Total Transportation Types	0.1611	0.1381	0.3189	0.1515	0.2304

As shown in Table 5, the results of the LOPCOW Analysis demonstrate that the foreign trade balance criterion is the most significant for determining the weights of foreign trade performance criteria, with values of 29.54% for road transportation, 31.91% for railway transportation, 26.83% for air transportation, 23.86% for maritime transportation, 40.55% for other transportation types, and 31.89% for the total of transportation types. Furthermore, the study identified the import criterion as the least significant, with values of 12.48% for road transportation, 12.06% for other transportation types, and 13.81% for the total of transportation types, while the trade volume criterion was found to be the least significant, with values of 12.68% for railway transportation, 11.95% for air transportation, and 15.62% for maritime transportation.

4.2. Findings of the CoCoSo Method

The year-by-year performance ranking of Türkiye's ten-year foreign trade data by transportation modes, obtained from TÜİK using the CoCoSo Method, is presented separately for road, railway, air, maritime, other, and total transportation modes. The findings are displayed in tabular form, with the steps of the CoCoSo Analysis for road transportation shown in Tables 6, 7, 8, 9, and 10. The foreign trade performance scores and rankings for railway, air, maritime, and other modes of transport, as well as the total, are presented in Table 11.

Table: 6
Road Transportation Decision Matrix

Criteria Directions Criteria / Years	Export Max	Import Max	Foreign Trade Balance Max	Foreign Trade Volume Max	Foreign Trade Coverage Ratio Max
2023	83066065.92	66942046.74	16124019.17	150008112.7	124.0865345
2022	78837774.67	59447024.84	19390749.82	138284799.5	132.618537
2021	68749375.68	48896681.49	19852694.19	117646057.2	140.601312
2020	53127587.69	41883476.8	11244110.88	95011064.49	126.8461736
2019	54461859.56	37177011.92	17284847.65	91638871.48	146.4933752
2018	52222467.59	39129379.96	13093087.63	91351847.56	133.4610148
2017	50988407.8	40374083.04	10614324.76	91362490.85	126.2899463
2016	49537436.35	36716500.27	12820936.08	86253936.62	134.9187313
2015	51946112.73	37840931.75	14105180.98	89787044.48	137.2749304
2014	61133175.85	40577283.08	20555892.78	101710458.9	150.6586228

The steps for calculating Türkiye's ten-year foreign trade performance ranking in road transportation using the CoCoSo Method are outlined in the tables. Foreign trade data on road transportation were used to construct the decision matrix shown in Table 6, as specified in Formula (7). The maximisation process for the normalised matrix in road transportation was carried out using Formulas (8) and (9), and the results are presented in Table 7.

Table: 7
Road Transportation Normalised Decision Matrix

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**
2023	1.0000	1.0000	0.5542	1.0000	0.0000
2022	0.8739	0.7520	0.8828	0.8161	0.3211
2021	0.5730	0.4030	0.9293	0.4924	0.6215
2020	0.1071	0.1709	0.0633	0.1374	0.1039
2019	0.1469	0.0152	0.6710	0.0845	0.8432
2018	0.0801	0.0798	0.2493	0.0800	0.3528
2017	0.0433	0.1210	0.0000	0.0801	0.0829
2016	0.0000	0.0000	0.2220	0.0000	0.4077
2015	0.0718	0.0372	0.3511	0.0554	0.4963
2014	0.3458	0.1277	1.0000	0.2424	1.0000

The Si value for road transportation, obtained using the criterion weights determined by the LOPCOW Method, is calculated with Formula (11) and shown in Table 8.

Table: 8
Road Transportation S_i Values

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio	S_i
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**	
2023	0.1552	0.1248	0.1637	0.1438	0.0000	0.5875
2022	0.1357	0.0939	0.2608	0.1173	0.0902	0.6978
2021	0.0889	0.0503	0.2745	0.0708	0.1745	0.6591
2020	0.0166	0.0213	0.0187	0.0197	0.0292	0.1056
2019	0.0228	0.0019	0.1982	0.0121	0.2368	0.4718
2018	0.0124	0.0100	0.0737	0.0115	0.0991	0.2066
2017	0.0067	0.0151	0.0000	0.0115	0.0233	0.0566
2016	0.0000	0.0000	0.0656	0.0000	0.1145	0.1800
2015	0.0112	0.0046	0.1037	0.0080	0.1394	0.2669
2014	0.0537	0.0159	0.2954	0.0349	0.2808	0.6807
W_j	0.1552	0.1248	0.2954	0.1438	0.2808	

The Pi values for road transportation were calculated using Formula (12), and the results are shown in Table 9.

Table: 9
Road Transportation P_i Values

Criteria Directions	Export	Import	Foreign Trade Balance	Foreign Trade Volume	Foreign Trade Coverage Ratio	P_i
Criteria / Years	**Max**	**Max**	**Max**	**Max**	**Max**	
2023	1.0000	1.0000	0.8400	1.0000	0.0000	3.8400
2022	0.9793	0.9651	0.9638	0.9712	0.7269	4.6063
2021	0.9172	0.8928	0.9786	0.9032	0.8750	4.5667
2020	0.7069	0.8021	0.4426	0.7517	0.5294	3.2329
2019	0.7425	0.5932	0.8888	0.7010	0.9533	3.8787
2018	0.6758	0.7294	0.6635	0.6955	0.7463	3.5105
2017	0.6142	0.7683	0.0000	0.6957	0.4970	2.5752
2016	0.0000	0.0000	0.6411	0.0000	0.7773	1.4183
2015	0.6645	0.6631	0.7341	0.6598	0.8214	3.5428
2014	0.8481	0.7735	1.0000	0.8157	1.0000	4.4372

The Pi values for road transportation were calculated using Formula (12), and the results are shown in Table 9. The relative performances of the options for road transportation have been assessed using the three different criterion strategy evaluations specified in Formulas (13), (14), and (15). The Ki values and performance rankings, calculated with $\lambda = 0.5$ using Formula (16), are shown in Table 10.

Table: 10
Alternative Relative Performance Rankings of Road Transportation

Criteria/Years	K_{ia}	K_{ib}	K_{ic}	K_i	Ranking
2023	0.1120	13.0828	0.8347	2.8197	4
2022	0.1342	15.5704	1.0000	3.2529	1
2021	0.1322	14.8586	0.9852	3.1638	2
2020	0.0845	4.1439	0.6294	1.7671	8
2019	0.1101	11.0673	0.8202	2.6224	5
2018	0.0941	6.1238	0.7008	2.0400	7
2017	0.0666	2.8157	0.4962	1.5315	10
2016	0.0404	4.1795	0.3013	1.6705	9
2015	0.0964	7.2106	0.7183	2.1685	6
2014	0.1295	15.1494	0.9649	3.1636	3

The decade of data on road transportation has been analysed using the CoCoSo Method. The final results and annual rankings are shown in Table 10. When evaluating the ranked results, the year with the best performance in road transportation from 2014 to 2023 was 2022, while the year with the poorest performance was 2017. The scores and rankings for foreign trade performance by transportation mode, obtained through the CoCoSo Analysis, are presented collectively for road, railway, air, maritime, other, and total transportation, as shown in Table 11.

Table: 11
Foreign Trade Performance Scores and Ranking Values of Transportation Types

Criteria	Road Transportation		Railway Transportation		Air Transportation		Maritime Transportation		Other Transportation Types		Total Transportation Types	
Yıllar	K_i	K_i	K_i	PS	K_i	PS	K_i	PS	K_i	PS	K_i	PS
2023	2.8197	4	2.8027	1	1.9776	4	2.3681	3	1.7737	5	1.9588	3
2022	3.2529	1	2.7519	2	2.0076	3	2.5186	1	1.5301	9	1.8794	6
2021	3.1638	2	1.9977	6	2.0651	1	2.4629	2	1.9145	2	2.2090	1
2020	1.7671	8	2.0648	5	1.3865	10	2.0874	6	1.8364	3	1.8945	5
2019	2.6224	5	2.0720	3	1.7967	8	2.1917	4	1.7881	4	2.0741	2
2018	2.0400	7	1.8544	8	1.7549	9	2.1181	5	1.7648	6	1.9192	4
2017	1.5315	10	1.7031	9	1.8742	6	1.7644	7	1.9490	1	1.7069	7
2016	1.6705	9	1.3629	10	2.0558	2	1.4511	8	1.4253	10	1.4506	10
2015	2.1685	6	1.9447	7	1.8884	5	1.4104	10	1.6745	7	1.6579	8
2014	3.1636	3	2.0698	4	1.8120	7	1.4400	9	1.6736	8	1.5681	9
λ	0.5											

The ten-year data for road transportation has been analysed using the CoCoSo Method. The final results and year-by-year rankings are shown in Table 11. When evaluating the ranked outcomes, the year with the best performance in road and maritime transportation between 2014 and 2023 was 2022, while the year with the top performance in railway transportation was 2023. The year 2021 was recognised as the best for air transportation and overall transportation, whereas 2017 was identified as optimal for other types of transportation. The study also revealed that road transportation performance in 2017 was the lowest, whilst railway transportation and other modes performed the worst in 2016. Air transportation underperformed in 2020, but maritime transportation hit its low point in 2015.

5. Discussion

In global competition, the success of foreign trade also depends on the actual conduct of trade. The modes of transportation directly affect several vital components of foreign trade, such as cost, speed, safety, and sustainability. Foreign trade conducted via different modes of transport should also be considered.

6. Conclusion and Evaluation

Foreign trade and transportation issues are emerging as significant areas of study in the contemporary global economy due to their social, cultural, and environmental effects. This study examines the relationship between foreign trade and transportation, specifically how different modes of transportation affect the performance of foreign trade. The research focuses on Türkiye and uses 10 years of foreign trade data (2014-2023), disaggregated by mode of transport, and evaluates them separately and in total. Two MCDM methods are particularly useful in this context: LOPCOW, which is used to derive weights for the problem's criteria, and CoCoSo, which is used to perform the actual ranking. The LOPCOW analysis identified the most significant criterion influencing all modes of transportation and the foreign trade balance. By raising the standard of living and the quality of life worldwide, foreign trade benefits everyone in every country. Goods, services, and capital are the three main categories of foreign trade, and globalisation increases both the quantity and the quality of foreign trade. Consequently, there is a steady increase in the foreign trade of such

countries, which boosts their national income and accelerates economic growth. Therefore, countries in the process of economic development must place particular emphasis on their foreign trade (Çalışkan, 2023: 68).

The finding that the foreign trade balance, which reflects the difference between exports and imports, is the main criterion for assessing foreign trade supports the conceptual theory. The import criterion was the least significant among the road, other, and total transportation types, whereas the trade volume criterion was the least significant across railway, air, and maritime transportation. Changes in import and export prices indicate whether trade terms are shifting in favour of or against the country (Yıldırım & Dura, 2007: 145). Domestic price increases are directly proportional to imports and exports; that is, when domestic prices rise, both imports and exports tend to increase. An inverse relationship exists between the exchange rate and imports: as the exchange rate increases, imports decrease (Sarı, 2010: 41). As shown, both exports and imports are important in determining commercial performance. However, in foreign trade, exports are of greater significance and should be emphasised over imports. The positive impact of foreign trade on total demand occurs only if exports exceed imports (Kurt & Zengin, 2016: 72). This supports the conclusion that the trade volume—defined as the sum of exports and imports—and the import criterion are the least significant.

According to the CoCoSo Analysis, the years with the highest performance rankings in foreign trade by transportation type were 2022 for road and maritime transport; 2023 for railway transport; 2021 for air and total transport; and 2017 for other transport. The years with the lowest performance rankings were 2017 for road transport; 2016 for railway transport, other transport types, and total transport; 2020 for air transport; and 2015 for maritime transport.

In analysing foreign trade performance by transportation types, the year 2022 can be identified as the best for road transportation due to several effective factors: regulations outlined in the Transport Organizer (TİO) document (Yalçınkaya & Say, 2022: 552), the level of exports being twice that of imports, and the reduction of negative impacts on trade after the pandemic (Bayram & Köse, 2022: 78-79). Additionally, the acceleration of new road and bridge construction, along with the prioritisation of maintenance and expansion of existing roads (General Directorate of Highways 2022 Activity Report, 2022: 11; Access Date: 11.06.2024), contributed to this performance. The increase in Türkiye's foreign trade volume, which heightened demand for road transportation (Öztaş, 2022: 27-32), also played a significant role. Conversely, 2017 stands out as the worst year for road transportation performance, linked to the depreciation of the Turkish Lira, the adverse effects of rising inflation and interest rates on trade (Boduk, 2022: 62), diplomatic tensions with oil and natural gas-rich countries (Doğan, 2021: 152-164), and the rise in fuel prices (Competition Authority Fuel Sector Review Report, 2024: 29, Access Date: 11.06.2024).

Upon analysing foreign trade performance by transportation mode, it is clear that 2023 is shaping up to be the best year for railway transportation. This is likely due to recent

substantial investments in railways, which are regarded as a more environmentally friendly, cost-effective, and secure mode of transportation compared with other options, particularly during the pandemic (Erkekoğlu & Şahin, 2023: 363; Akalan, 2023: 60; Arslan & Öztürk, 2023: 265).

The identification of 2016 as the worst year for railway transportation performance can be attributed to the negative impact of maintenance, repair, and renewal activities on railway transportation capacity and efficiency (Strategy Development Department Railway Sector Report, 2016: 11-12, Access Date: 07.06.2024), high inflation rates, and fluctuations in exchange rates that create cost pressures in the railway transportation sector (Central Bank of the Republic of Türkiye, Monetary Policy Committee Meeting Summary, 2016: 3).

In analysing foreign trade performance by transportation types, 2021 is identified as the best year for air transportation, attributable to the easing of pandemic restrictions. This led to increased tourism, enabling the development of air transportation and more frequent flights (Ünüvar & Aktaş, 2022: 133). Additionally, discounts offered by businesses in tourist areas during the pandemic contributed to a rise in tourists and air travel (Ünver, 2021: 53-55), alongside capacity increases at Istanbul Airport and the addition of new destinations (Mor & Ilıcalı, 2022: 78). Conversely, 2020 is seen as the worst year for air transportation, mainly due to a significant decline in passenger numbers caused by travel restrictions and quarantine measures during the pandemic (Tüysüz & Sarıışık, 2024: 376; Erkekoğlu & Şahin, 2023: 359-360).

In the analysis of foreign trade performance by transportation types, the identification of 2022 as the best year for maritime transportation performance can be attributed to the sudden increase in exports resulting from the collective export of products that were held in ports during the pandemic as pandemic rules eased (Oran & Gökmen, 2021: 378-385), as well as the cost advantages of maritime transportation for heavy tonnage loads (Pehlevan & Ricci, 2022: 107) and the increase in port infrastructure capacity (Tunalı & Akarçay, 2022: 109). The designation of 2015 as the worst year for maritime transportation performance can be attributed to the explosion of hazardous materials in Tianjin, China (Ünal & Usluer, 2015: 17), and the rise in passenger volumes transported in Turkish ports from 2008 to 2015, followed by a downward trend after 2015 (Bozkurt et al., 2018: 4).

In analysing foreign trade performance by transportation types, the recognition of 2017 as the most successful year for other transportation categories can be linked to the strategic processing of oil discovered by the Turkish Petroleum Corporation (TPAO) in collaboration with foreign firms during 2017-2018 (Tepealtı, 2009: 33). Additionally, it relates to the potential of becoming a transit hub for energy routes such as the Eastern Mediterranean line (Güneş & Arslan, 2018: 33-44; Alnour & Önden, 2023: 639) and the Turkish Stream Gas Pipeline (Usman et al., 2022: 7287-7258; İlter & Kınık, 2017: 194-196). Conversely, 2016 is identified as the worst year for other transportation categories, primarily due to declining oil prices, which adversely affected the energy transportation sector, and

rising costs of oil and natural gas transported via pipelines (TPAO Crude Oil and Natural Gas Sector Report, 2016: 15-17).

In analysing foreign trade performance by transportation mode, 2021 stands out as the best year for total transportation activities. This can be attributed to efforts to develop the Middle Corridor, which has a capacity of 10 million tons of cargo and 200,000 containers, managed by members of the Organisation of Turkic States (OTS). These efforts resulted in a 101% increase in cargo volume in 2021 compared to the previous year (Baghırov, 2022: 62-63). Additionally, as the effects of the COVID-19 pandemic began to lessen, the recovery process contributed to increased trade and tourism, thereby benefiting the transportation sector (Taşkın & Akıncı, 2021: 767). Conversely, 2016 was identified as the worst year for total transportation types. This downturn can be traced to the downing of a Russian warplane on 24 November 2015, by Türkiye, which was one of Türkiye's largest trading partners, due to violations of Turkish airspace (Keser & Meral, 2016: 31). This incident led to the imposition of an embargo and the decision to halt exports (Güleç, 2016: 36-40).

This research assesses Türkiye's foreign trade performance across transport modes and provides a comprehensive overview of the current situation. Drawing on foreign trade theories such as Comparative Advantage and Factor Proportions, which position Türkiye in relatively advantageous positions, the study provides a foundation for policymakers to determine the most suitable transportation modes for conducting foreign trade more efficiently, swiftly, and cost-effectively. It also offers guidance, based on the same research, for making better strategic investments in logistics infrastructure and implementing more effective transportation policies.

The results focus on six specific modes of transportation: road, railway, air, maritime, and a few others, as well as a total for all types of transport, alongside five foreign trade indicators: exports, imports, trade balance, overall trade volume, and trade extent. All data covers ten years and is analysed using two techniques: LOPCOW and CoCoSo. Taken as a whole, the findings align with the existing literature and strongly support the conceptual theory. Additionally, the unique approach of examining transportation and foreign trade together adds an innovative aspect to the research.

This research employed MCDM methods to evaluate how different transportation modes influenced foreign trade performance, utilising five criteria: exports, imports, trade balance, trade volume, and trade coverage ratio. It is also advisable that future research employing MCDM methods incorporate additional criteria. Three alternative criteria that could serve as bases for future assessments are transportation costs, the Logistics Performance Index (LPI), and the environmental impact of transportation modes. The findings offer a clear overview of how different modes of transportation, both collectively and individually, perform in foreign trade over time. The research outcomes act as a guide for decision-makers and policymakers.

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