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Determination of Logistics Performance of G20 Countries Using Quantitative Decision-Making Techniques

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Abstract: Today, the increase in competition with globalization has caused logistics to gain importance, with international trade as one of its basic elements. Developments in the transportation and logistics sector affect economic growth through their effects on production, consumption, and trade. Similarly, international trade and economic growth also support the development of the transportation and logistics sector. From this perspective, logistics is an indicator of development. Nowadays, logistics is a constantly developing and growing sector. The aim of this study is to conduct performance rankings and cluster analyses of G20 countries in 2023 and to compare the results with the logistics performance index (LPI) scores published by the World Bank. Our assumption is that the results of the analysis and the LPI index would be the same or similar. The findings obtained as a result of both analyses are largely similar to the LPI ranking presented by the World Bank.

Keywords: logistics performance index; G20; clustering analysis

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1. Introduction

Intense competition at the global level requires companies to prepare and deliver their products faster. Effective logistics services not only reduce the costs of trade between countries but also increase the security and speed of access of products to the points where they are needed [1] (p. 2982).

The former perception of logistics was simply based on supply chain management, whose purpose was providing the delivery of all items needed for manufacturing in an appropriate manner. Yet, with the modernization and globalization of the market, this term gained in dimension, including, for example, connections between time and location [2] (p. 468). The logistics industry's current definition is considered a whole for functionality, transportation, communication, delivery, circulation, and storage operations [3] (p. 66).

Logistics is one of the fundamental elements of trade [1] (p. 2983), and logistics performance significantly affects bilateral trade volume. This is an element that increases competitiveness not only for companies but also for countries that realize the importance of logistics in world trade [4] (p. 236).

The LPI is an indicator developed by the World Bank that shows the logistics performance of countries according to logistics quality. The LPI is a tool designed to help countries identify the challenges and opportunities they face in their work in trade and logistics, as well as to make recommendations to improve a country's performance [5] (p. 13). The World Bank has been publishing an LPI report periodically since 2007.

The LPI provides important information about the logistics activities of countries. This index provides a general perspective on the status of countries' customs regulations, logistics costs, and infrastructure used in land–sea–air transportation. The LPI has become

an important measurement, comparison, and rating criterion for the logistics competencies of countries. Moreover, any increase in LPI dimensions significantly affects a country's trade [1] (p. 2983). Thanks to this index, it has become easier to compare the efficiency of the logistics activities of different countries.

This study aimed to rank the logistics performance of G20 countries in 2023 by comparing them with the LPI scores published by the World Bank. TOPSIS and cluster analysis were used in this study. It was assumed that the results obtained in this study and the LPI values would be similar. In this study, the TOPSIS method was primarily preferred in order to rank the performance of the countries by taking into account the LPI subcomponents and comparing them with the index values. Then, cluster analysis was carried out to group the countries according to subcomponents.

The remainder of this paper is structured as follows: In the second section, a detailed literature review on the subject is provided. In the third section, the conceptual framework is given; in this context, LPI and its importance, ranking, and the situation of G20 countries in terms of LPI were examined. The fourth section focuses on the methodology in this research. In the fifth section, the findings and a discussion are given; in the last section, the results and suggestions on the subject are discussed.

2. Literature Review

Analyzing the efficiency of logistics operations constitutes an important research area in the literature. Many researchers have worked on efficiency measurement for different types of transportation such as road, airline, and railway. While many researchers have evaluated logistics performance at the micro level, few have evaluated it at the macro level. While the micro-level analysis focuses on company-specific efficiency, macro-scale analysis evaluates the logistics performance of countries [6] (p. 37).

The following examples can be given for articles that discuss logistics performance from a micro perspective: Chan et al. [7] used the AHP method to measure logistics performance in the postal services sector in their study. Jayathilaka et al. [8] examined the relationship between the LPI and gross domestic product (GDP) in 142 countries for the years 2007–2018. Panel regression was used in the analysis. As a result of the analysis, it was found that there was a positive relationship between the LPI and net exports for the continents of Asia, Europe, and Oceania.

Saini and Hrusecka [9] examined the impact of the LPI and ease of doing business index (EODB) and logistics cost (LC) on economic development using Pearson correlation analysis and detailed fuzzy qualitative comparative analysis. The results showed that the LPI has positive consequences on economic development.

Marti et al. [10] used DEA and analysis of variance (ANOVA) to measure the logistics efficiency of countries and test the effect of income and geographic regions on efficiency. In the DEA, three LPI subdimensions, i.e., "customs", "infrastructure" and "logistics quality", were considered as inputs, while the other dimensions, "international shipment", "tracking/tracing", and "timeliness" were considered as outputs. The study found a significant relationship between logistics performance, income, and geographical area, with the analysis showing that high-income countries were in the best-performing group. Stojanovic and Ivetic [11] showed how delivery methods in international trade affect LPI scores.

Shepherd and Sriklay [12] aimed to expand the scope of the LPI published by the World Bank to include 30 additional countries and 13 additional years. It tried to determine the factors affecting LPI scores using a survey method.

Puertas et al. [2] evaluated the relationship between logistics performance and export competition in Europe in 2005 and 2010 by comparing them with a mathematical method. As a result, they concluded that the European Union made positive contributions to logistics performance, and as the export amount of member countries increased, their logistics performance increased.

Avelar-Sosa et al. [13] investigated the effects of traditional and international logistics policies on supply chain performance through structural equation modeling. As a result, they revealed that traditional logistics policies have a direct effect on inventory; this effect increases customer satisfaction and creates positive economic effects.

Lin and Cheng [14] evaluated the relationship between logistics performance indices and gross domestic product in the countries they considered with linear regression. They also evaluated the situation of neighboring countries and concluded that the logistics performance indices of the countries depend on the logistics performance of their neighbors rather than GDP.

Yusufkhonov et al. [15] proposed strategies to improve Uzbekistan's position in the LPI. They used a global survey of logistics professionals. As a result, certain problems were identified, and recommendations were made to improve the situation in Uzbekistan.

Larson [16] examined the relationships between logistics performance and social, economic, and environmental sustainability dimensions with regression analysis. They found that social sustainability and prosperity were associated with high levels of logistics performance.

Marti et al. [1] used the center of gravity approach to determine the importance of the LPI in international trade and predicted that any improvement in the index for developing countries would also lead to growth in trade.

A study on the evaluation of the logistics performance of G20 countries was conducted by Ulutas and Karakoy [17]. In the study, G20 countries were ranked in terms of their logistics performance in 2018 by using standard deviation (SD) and weighted aggregated sum product assessing (WASPAS) methods, which are multicriteria decision-making methods. When the calculated rankings were compared with the original LPI rankings, it was revealed that 15 out of 19 countries were ranked exactly the same, and only 4 countries differed in their rankings. It was also determined that there was a strong correlation between the ranking obtained in the study and the original LPI ranking. Although the method used in this study is different, the purpose and results of our study are significantly similar to those of that study.

Turkoglu and Duran [18] evaluated the 2018 logistics performance of G20 countries with the CRITIC-based GIA and WASPAS methods. In the study, they determined that "Logistics Quality and Competence", one of the subcomponents of the LPI, is the most important variable, and the top three countries were Germany, Japan, and the United Kingdom. They also stated that the logistics ranking obtained in the study was highly similar to the LPI scores. It seems that the results of that study are compatible to those of our study.

In the study conducted by Orhan [19], the logistics performance of Turkey and EU countries was compared. For this comparison, the EDAS method, which is similar to the TOPSIS method, was preferred, and the LPI subcomponents were analyzed as in our study. As a result of the analysis, it was determined that 19 countries maintained their ranks, 5 countries rose to the top, and 6 countries fell to he lower ranks. These results are similar to those of our study.

Rezaei, Roekel, and Tavasszy [20] determined the severity levels of the subcomponents of the LPI using the best–worst method (BWM). As a result of the analysis, it was determined that the most important component was infrastructure and the least important component was tracking and monitoring.

In Qazi's study [21], the interaction between LPI variables and risks (economic, political, individual, etc.) was determined with the data-based Bayesian belief network model. As a result of the analysis, it was determined that there was a strong correlation between individual risks and the LPI variables. Additionally, economic risks have been found to greatly affect LPI variables. Beysenbaev and Dus [22] found differences in the logistics performance index coefficients in their study. An attempt was made to detect the differences between the determined coefficients and the LPI ranking. As a result of the analysis, it was determined that the top five countries were Denmark, Belgium, the Netherlands, Germany, and Austria, respectively.

In Liu et al. [23], the relationship between the LPI values and CO_2 emissions of 42 Asian countries between 2007 and 2016 was analyzed using a regression method. As a result, it was determined that international shipping, which is an LPI subcomponent, reduces CO_2 emissions, while the timeliness subcomponent increases emissions.

Roy et al. [24] analyzed the relationship between LPI values and GDP with the multivariate adaptive regression spline (MARS) method. First, the countries included in the LPI were clustered using the K-means method, and then the MARS method was applied. As a result of the analysis, it was determined that there was a relationship between LPI values and GDP.

In Pesquera's [25] study, the relationship between the LPI subvariables and scale efficiency of 133 countries between 2007 and 2018 was determined using data envelopment analysis, and it was determined that the LPI values affected scale efficiency. Sergi et al. [26] measured the effect of the subcomponents of the global competitiveness index (GCI) on LPI values using the ANOVA method. The continents subject to analysis were Africa and Asia, as well as EU countries. Each country group was treated as a cluster. As a result of the analysis, it was determined that the human factor affected the LPI values of EU countries, infrastructure affected the index in Asian countries, and all factors affected the LPI of African countries.

Mesic et al. [5] ranked the Western Balkan countries by taking into account the World Bank's 2018 LPI subcomponent values. In the study, the criteria importance through intercriteria correlation (CRITIC) method was used to determine the weights of the LPI subcomponents, and the measurement alternatives and ranking according to compromise solution (MARCOS) method was used to rank the countries. According to the results obtained, it was determined that Serbia ranked first.

Comparing the import–export data of Korea and 161 countries whose LPI subcomponents were published for the years 2010–2018, Song and Lee [27] found that there was a significant relationship between LPI components and import–export. Ilangasekara and Premarathne [28] tried to examine the reasons for the infrastructure variable being Sri Lanka's lowest LPI subcomponent. In the analysis using the AHP method, data collected by survey method from 60 experts were used. As a result of the analysis, it was determined that in order to develop infrastructure, which is a subcomponent of LPI, the port infrastructure, warehouse and transfer, information technology infrastructure, highway infrastructure, airport infrastructure, and railway infrastructure should be developed.

Ulkhaq [29] conducted a cluster analysis by taking into account the LPI subcomponent values of 160 countries announced by the World Bank in 2018. The countries were gathered in three clusters using k-means, k-medoids, and clustering large applications methods. It was found that the countries in the first cluster were the countries with the best performance.

The literature shows that logistics performance has been evaluated with different methods. It is also noteworthy that the LPI data published by the World Bank have frequently been used, but there are very few studies ranking G20 countries. This paper presents an example of international performance evaluation in the field of logistics performance analysis and provides a comparative evaluation of different countries. In addition, this study demonstrates the accuracy of the scores prepared by taking into account the LPI subcomponents using the TOPSIS method and proposes a new method in which the TOPSIS method and cluster analysis are used together for logistics performance measurement and evaluation. No study has been found in the literature that evaluates logistics performance using the TOPSIS and clustering methods. Therefore, this study provides a new approach for logistics performance evaluation. Since these two methods have not been applied together in any study to evaluate logistics performance, the current study is expected to contribute to the literature. In this study, the logistics performance of the countries included in the G20 were evaluated with the real data provided by the World Bank and compared with the scores determined in the analysis. This study offers an innovative approach in this respect.

3. Conceptual Framework

3.1. Logistics Performance Index (LPI) and Its Importance

High logistics costs and low logistics service levels constitute an obstacle to trade, foreign direct investment, and therefore economic growth. For these reasons, improving logistics performance has become an important development policy goal. The LPI was developed to help countries develop logistics reform programs to increase trading ability and competitiveness. This index, which evaluates the logistics systems and infrastructure activities of countries, is calculated by the World Bank [30] (p. 3).

The LPI is one of the tools published by the World Bank that evaluates the logistics performance of a country. The LPI is based on a survey of logistics professionals in the included countries regarding their perceptions of the country's logistics performance [29] (p. 1011). Determining logistics performance, which is an important indicator of the development levels of countries, has gained in importance. Indeed, by revealing country performance, it is possible to identify the failing elements and develop remedial policies.

The LPI is an indicator developed to measure the performance of the logistics industry based on a survey that has been widely used worldwide since 2007 [29] (p. 1010). The World Bank subjects countries to logistics efficiency, quality, and adequacy measurements. The LPI helps countries identify the challenges and opportunities they face in their logistics performance and what they can do to improve their performance [31].

The LPI has been introduced as the most important evaluation criterion that is impartial, objective, and universal for measuring and comparing the logistics competence and quality of participating countries. In addition to being the most comprehensive international comparison tool for measuring the logistics performance of countries, the LPI provides an analysis of the performance trends, revealing trends over time [32] (p. 6). Therefore, the LPI is an important performance indicator for countries.

The LPI, calculated by the World Bank with data obtained through a survey, determines the performance of countries in the following six dimensions:

a. Efficiency of customs and other border operations measures the speed, simplicity and predictability of official procedures carried out by customs institutions.
b. Logistical quality of trade and transportation infrastructure evaluates the quality of road, sea, railway, and air transportation infrastructure. The assessment of survey participants in this infrastructure relates to both the storage and transportation of goods according to their mode of transport.
c. Ease and cost of arranging international shipments measures whether transportation can be achieved at competitive prices.
d. Quality of logistics services and logistics competence: Logistics and forwarder companies measure the quality of logistics services offered by customs agencies.
e. Tracking and traceability of shipments: It measures the traceability of the route of shipments until their delivery to the final customer.
f. Frequency of shipments reaching the recipient on schedule measures on-time delivery of the shipment. It is important to take this factor into account because, due to the current high degree of competition, exceeding expected delivery times is unacceptable [10] (p. 177), [33] (p. 8).

Expert logistics companies answer the surveys under these six headings, scoring the logistics performance of countries between one (worst) and five (best). By taking the average of these scores, logistics performance indices and country rankings are created according to the year [34] (p. 233). The LPI has become a fundamental tool for explaining the relationship between international trade and logistics infrastructure. The LPI has helped identify logistics-related problems and priorities and strengthened communication between the public and private sectors [35] (p. 264).

Unfortunately, the LPI is subjective, and participants are experts of logistics working in international companies. However, the logistics performance of a country depends on total performance of individual logistics companies. Consequently, individual companies' performances should be analyzed rather than macro effects [36] (p. 281).

3.2. Global Logistics Performance Index of G20 Countries

The first logistics performance indices of countries were calculated by the World Bank in 2007. Seven criteria were used in the measurement in 2007, and measurements were made in six areas in subsequent measurements. A scale was used to measure the logistics performance index, with one representing the lowest score and five representing the highest score.

The G20, which includes the world's largest economies, includes 19 member countries and the European Union (EU Commission and EU Council presidents): Germany, USA, Argentina, Australia, Brazil, China, Indonesia, France, South Africa, Korea, India, United Kingdom, Italy, Japan, Canada, Mexico, Russian Federation, Saudi Arabia, and Turkey.

In terms of their economic size, G20 member countries own approximately 85% of all goods and services produced in the world in monetary terms and approximately three-quarters of world trade. Therefore, the harmonious and effective work of the G20 countries plays an important role in stabilizing the global economy.

Table 1 shows the 2023 LPI scores and rankings of the G20 countries. The LPI ranking refers to the rank among 139 countries.

Table 1. Logistics performance index and ranking of G20 countries (2023).

Country	LPI Score	LPI Ranking
Germany	4.1	3
Canada	4.0	7
Japan	3.9	13
France	3.9	13
USA	3.8	17
Korea	3.8	17
Australia	3.7	19
Italy	3.7	19
China	3.7	19
United Kingdom	3.7	19
South Africa	3.7	19
Turkey	3.4	38
Saudi Arabia	3.4	38
India	3.4	38
Brazil	3.2	51
Indonesia	3.0	61
Mexico	2.9	66
Argentina	2.8	73
Russian Federation	2.6	88

Source: [37].

The country with the highest LPI score among the G20 countries in 2023 was Germany, which ranked 3 among 139 countries. Canada and Japan followed Germany. Among the G20 countries, the countries with the lowest LPI scores were Mexico, Argentina, and the Russian Federation. These countries ranked 66th, 73rd, and 88th in the overall rankings, respectively.

4. Research Methodology

The aim of this study was to create a performance ranking with the TOPSIS method using the subcomponents of the logistics performance index of G20 countries in 2023. In addition, it was aimed to compare the results obtained with the World Bank's LPI data and to group the countries by performing cluster analysis. In the first stage of the application, performance evaluation analyses were conducted with the TOPSIS method using the six variables that are the determinants of the LPI, and countries were ranked according to the LPI subvariables. In addition, the obtained scores were compared with the World Bank LPI scores to determine to what extent they were similar. In the second part, clustering analysis was performed; thus, countries were grouped, and more summary information

was obtained. The TOPSIS method was carried out in Excel 2010, and the clustering analysis is carried out using the SPSS 21 package program.

To rank the performance of the G20 countries using the LPI subcomponents, the TOPSIS method, which is suitable for alternative ranking and is one of the multicriteria decision-making techniques, was chosen. Cluster analysis was also used in this study because it allows creating a group by bringing together elements with similar characteristics.

The G20 countries subject to analysis included Germany, USA, Argentina, Australia, Brazil, China, Indonesia, France, South Africa, Korea, India, United Kingdom, Italy, Japan, Canada, Mexico, Russian Federation, Saudi Arabia, and Turkey. The determinants of the logistics performance index were the scores for customs, infrastructure, logistics competence and quality, international shipment, timeliness, and tracking and monitoring.

4.1. TOPSIS Analysis

TOPSIS method is one of the multicriteria decision-making techniques and an intuitive method that helps to rank alternatives. The basic assumption in performing the sorting is based on the calculation of the distance to the ideal solution point by finding positive and negative ideal points. The aim is to obtain results that are closest to the positive ideal point and furthest from the negative ideal point. One of the important points that must be decided in order to apply the method is the weights. The weighting method used in practice is the "Equal Weighting" method. In this method, which is the simplest and most commonly used method, it is assumed that the criteria are of equal importance [38] (pp. 7–8).

The first stage of the TOPSIS method, which is carried out in six steps, is creating the decision matrix in which the variable values corresponding to the countries are determined.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & & . \\ . & . & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \quad (1)$$

In the second step, after taking the squares of each variable and adding the columns, the variable value in the decision matrix is normalized by dividing it by the square root of the column sum. Thus, the R matrix is obtained.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \qquad \mathrm{i} = 1, \dots, \mathrm{m} \quad \mathrm{j} = 1, \dots, \mathrm{n} \quad (2)$$

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & . & & . \\ . & . & & . \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad (3)$$

The third step is creating a weighted normalized decision matrix. The important point is that the sum of the determined weights is equal to 1. The equal weight method was used in the analysis. Since the number of variables considered in the analysis was 6, 1/6 = 0.167 was calculated as the weight coefficient and each normalized variable was multiplied by the determined weight coefficient. If "w" denotes the weight coefficient, then

$$\sum_{i=1}^{n} w_i = 1 \quad (4)$$

$$\mathbf{V_{ij}} = \begin{bmatrix} \mathbf{w_1 r_{11}} & \mathbf{w_2 r_{12}} & \cdots & \mathbf{w_n r_{1n}} \\ \mathbf{w_1 r_{21}} & \mathbf{w_2 r_{22}} & \cdots & \mathbf{w_n r_{2n}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \mathbf{w_1 r_{m1}} & \mathbf{w_2 r_{m2}} & \cdots & \mathbf{w_n r_{mn}} \end{bmatrix} \quad (5)$$

The fourth step is determining the distance to the positive and negative ideal solutions. For the positive ideal solution, the weighted value is subtracted from the maximum value determined in the columns in the previous stage, the resulting result is squared, and the square root of the sum of the resulting rows is calculated. In the negative ideal solution, the minimum value in the columns is determined, and the square root of the row totals is calculated after subtracting the weighted value from the minimum value. The largest value in the columns is called ideal (S^*), and the smallest value is called negative ideal (S^-).

$$S^* = \left\{ \left(\max_{\mathrm{i}} v_{ij} | j \in J \right), \left(\min_{\mathrm{i}} v_{ij} | j = J \right) \right\} \quad S* = \left\{ v_1^*, v_2^*, \ldots, v_n^* \right\} \quad (6)$$

$$S^- = \left\{ \left(\min_{\mathrm{i}} v_{ij} | j \in J \right), \left(\max_{\mathrm{i}} v_{ij} | j = J \right) \right\} \quad S^- = \left\{ v_1^-, v_2^-, \ldots, v_n^- \right\} \quad (7)$$

In the fifth step, the relative closeness to the ideal solution is calculated using the Euclidean distance approach. The deviation values obtained here are called the positive ideal (S_i^*) and negative ideal (S_i^-) discrimination measure.

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^* \right)^2} \quad \mathrm{i} = 1, 2, \ldots, \mathrm{m} \quad (8)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2} \quad \mathrm{i} = 1, 2, \ldots, \mathrm{m} \quad (9)$$

The last stage is the calculation of the relative closeness value (C_i^*). The negative ideal result is divided by the sum of the positive and negative ideal results. The results obtained are sorted from largest to smallest. The largest result shows the highest performance because it is the result closest to the ideal solution.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad \mathrm{i} = 1, 2, \ldots, \mathrm{m} \quad (10)$$

4.2. Clustering Analysis

Cluster analysis was used to group similar countries together. Cluster analysis is a method used to see homogeneity or heterogeneity between the units subject to analysis. While units located in the same cluster are considered homogeneous, units located in different clusters are considered heterogeneous to each other. Two different methods are used to identify clusters. The first of these methods is hierarchical clustering. The hierarchical clustering method first assumes that all units are a single cluster and reduces the number of clusters by using similarity matrices. In this method, the number of clusters cannot be determined at the beginning of the analysis. The number of clusters can be determined through the resulting dendrograms (similar to a tree diagram) [39] (p. 703). The second method is the nonhierarchical clustering method. Although this method is applied for cases in which the number of clusters is known in advance and the number of units is high, it requires the subjective judgment of the researcher.

5. Findings

5.1. TOPSIS Analysis Findings

The 19 countries and variable values of the countries subject to analysis were analyzed with the TOPSIS method. The positive and negative ideal solutions and relative closeness

value results obtained as a result of the TOPSIS analysis of the LPI subvariable values of the 19 countries subject to study are given in Table 2.

Table 2. Calculating the distances to the created positive ideal (S^*) and negative ideal (S^-) solutions.

Country	S^-	S^*	C^*	Ranking
Germany	0.040109	0.001150	0.972136	1
USA	0.033797	0.007859	0.811330	5
Argentina	0.007590	0.034007	0.182476	18
Australia	0.032436	0.010168	0.761344	7
Brazil	0.016049	0.024919	0.391747	15
China	0.030667	0.011362	0.729667	9
Indonesia	0.012113	0.029874	0.288498	16
France	0.034467	0.007883	0.813857	4
South Africa	0.029347	0.012880	0.694980	11
Korea	0.033383	0.007956	0.807541	6
India	0.022439	0.020604	0.521323	14
United Kingdom	0.030302	0.011333	0.727799	10
Italy	0.030265	0.010946	0.734381	8
Japan	0.036256	0.005537	0.867517	3
Canada	0.039713	0.001564	0.962119	2
Mexico	0.011520	0.031484	0.267888	17
Russian Federation	0.000001	0.040617	0.000014	19
Saudi Arabia	0.022151	0.019512	0.531677	13
Turkiye	0.022800	0.019248	0.542234	12

The TOPSIS analysis results are compared with the logistics performance indices in Table 3. The TOPSIS analysis results and index values for nine countries are the same: Germany, Argentina, Australia, Brazil, Indonesia, Canada, Mexico, Russia, and Saudi Arabia. While there is generally a one-rank difference between the index value of the other countries and the TOPSIS analysis, India was ranked two lower according to the TOPSIS result, and Turkey was ranked two places higher. The main reason why the LPI values and TOPSIS analysis results are close is that the values of many countries in the index table are the same and/or close to each other. According to the performance ranking obtained as a result of TOPSIS, the first five countries in descending order are Germany, Canada, Japan, France, and the USA.

Table 3. Comparison with LPI values.

Country	LPI Score	LPI Ranking	TOPSIS Ranking	Change
Germany	4.1	1	1	No
USA	3.8	6	5	Increase
Argentina	2.8	18	18	No
Australia	3.7	7	7	No
Brazil	3.2	15	15	No
China	3.7	8	9	Decrease
Indonesia	3	16	16	No
France	3.9	3	4	Decrease

Table 3. *Cont.*

Country	LPI Score	LPI Ranking	TOPSIS Ranking	Change
South Africa	3.7	10	11	Decrease
Korea	3.8	5	6	Decrease
India	3.4	12	14	Decrease
United Kingdom	3.7	11	10	Increase
Italy	3.7	9	8	Increase
Japan	3.9	4	3	Increase
Canada	4	2	2	No
Mexico	2.9	17	17	No
Russian Federation	2.6	19	19	No
Saudi Arabia	3.4	13	13	No
Turkey	3.4	14	12	Increase

5.2. Clustering Analysis Findings

In this study, the Ward method, one of the hierarchical clustering methods, was applied. The main purpose of using hierarchical cluster analysis is to not know how many clusters will form in advance and to create clusters by taking into account the relationships that emerge using all the variables. The main reason for applying the Ward method is to create clusters in a way that maximizes homogeneity within the cluster and heterogeneity between clusters.

Figure 1 shows the cluster analysis dendrogram created according to the variables for 2023. Table 4 shows the cluster analysis results for G20 countries as a whole. In determining the number of clusters, the distances in the dendrogram are taken into account. The number of clusters is determined by taking into account the distance between one and two, as forming many clusters is not desired in practice, and it can better highlight the differences in the variables.

When the dendrogram was examined, it was determined that a total of three clusters formed in the range of 1–2. The results of Ward cluster analysis performed with three clusters are shown in Table 4.

As a result of the analysis, it was determined that there were 11 countries in the first cluster, 4 countries in the second cluster, and 4 countries in the third cluster. The lowest average logistics performance index value of the countries in the first cluster was 3.8, and the lowest value was 3.7 among the countries with the highest performance. The lowest logistics performance index average of the countries in the second cluster was 2.8, and the lowest index value was 2.6 among the countries with the lowest performance. The lowest index value of the countries in the third cluster was 3.2, and the average value was 3.35, and they were in the second position in the performance ranking. Additionally, descriptive statistics for the clusters are given in Table 5.

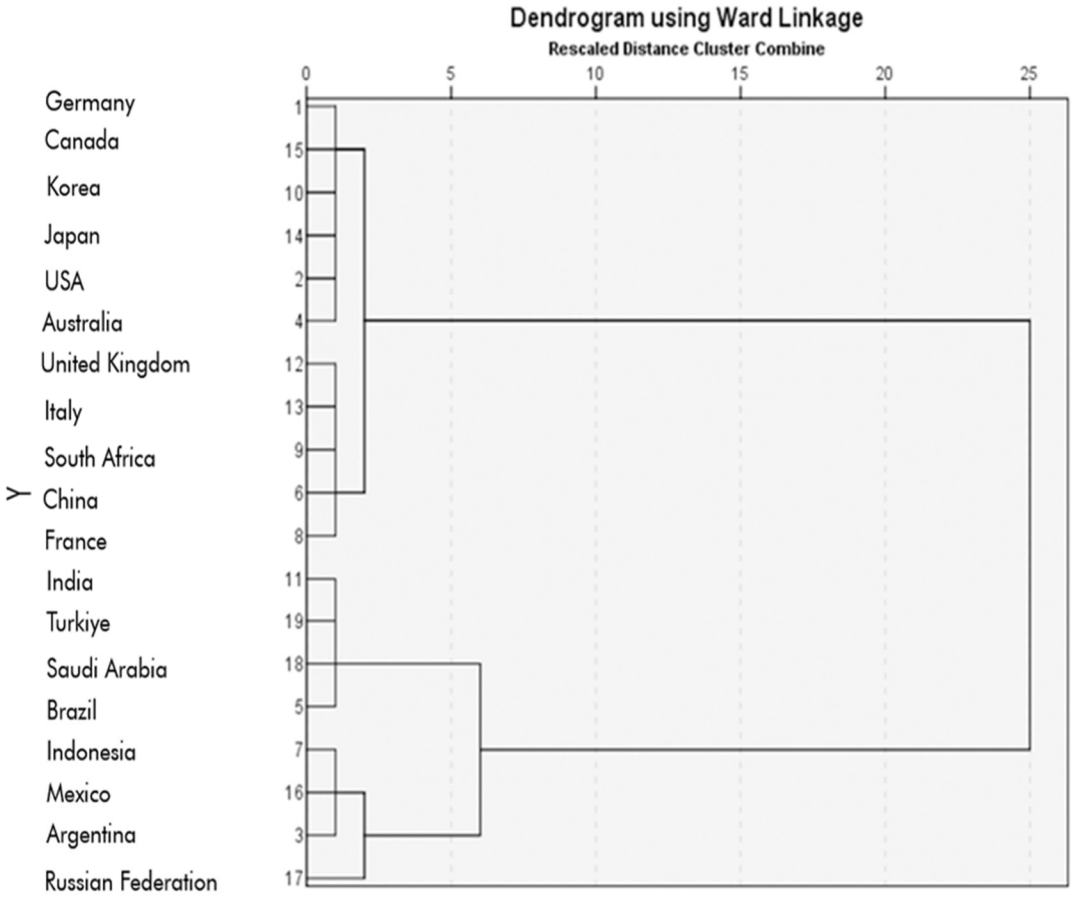

Figure 1. Dendrogram result of clustering analysis according to determinant variables of logistics performance index in 2023.

Table 4. Clustering analysis results.

Cluster 1	Cluster 2	Cluster 3
Germany	Argentina	Brazil
USA	Indonesia	India
Australia	Mexico	Saudi Arabia
China	Russian Federation	Turkey
France		
South Africa		
Japan		
Canada		
United Kingdom		
Italy		
Korea		

According to the descriptive statistics prepared as a result of the cluster analysis, it was determined that the largest deviation from the average was in the international shipment score (0.24 on average), and this shows that countries were further away from the average international shipment score. The average deviation in customs, quality, and timeliness scores was 0.16; the average deviation was 0.17 in the infrastructure score and 0.18 in the monitoring score. It was seen that there was more deviation in the index variable values of the countries in the second cluster.

The results of the clustering and TOPSIS analysis in Table 6 were considered as a whole, and the results obtained were compared.

Table 5. Descriptive statistics for clusters.

Determinants of Logistics Performance İndex	Cluster 1 (11 Countries)		Cluster 2 (4 Countries)		Cluster 3 (4 Countries)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Customs Score	3.66	0.25	2.6	0.18	2.98	0.05
İnfrastructure Score	3.98	0.24	2.8	0.08	3.35	0.19
Logistics Qualification and Quality Score	3.91	0.18	2.8	0.18	3.4	0.12
International Shipping Score	3.48	0.18	2.7	0.29	3.28	0.26
Timeliness Score	3.87	0.18	3.2	0.26	3.58	0.05
Track and Trace Score	3.99	0.15	2.88	0.26	3.4	0.14

Table 6. General analysis results.

Country	Clustering Result	TOPSIS Ranking	LPI Ranking (World Bank)
Germany	1	1	1
USA	1	5	6
Australia	1	7	7
China	1	9	8
France	1	4	3
South Africa	1	11	10
Korea	1	6	5
United Kingdom	1	10	11
Italy	1	8	9
Japan	1	3	4
Canada	1	2	2
Argentina	2	18	18
Indonesia	2	16	16
Mexico	2	17	17
Russian Federation	2	19	19
Brazil	3	15	15
India	3	14	12
Saudi Arabia	3	13	13
Turkey	3	12	14

The clustering and TOPSIS results show that the 11 countries in the first cluster are the countries with the highest LPI values. This result is the same as the first 11 countries in the World Bank's LPI rankings. The four countries in the second cluster are the countries with the lowest LPI values. This result is the same as the World Bank's findings. Similarly, in the analysis, four countries in the third cluster, which includes countries with medium performance, were also found to have medium performance in the World Bank's results. All results from the analysis are exactly the same to the findings of the World Bank.

6. Discussion

In this study, the LPI scores published by the World Bank were calculated using different methods using the subcomponents, and an alternative ranking was obtained. It was determined that the findings obtained from the analysis made with 2023 data were significantly similar to the LPI scores published by the World Bank. When the calculated ranking was compared with the original LPI ranking, it was revealed that the ranking positions of 9 out of 19 countries were exactly the same, and there were differences in the rankings of 10 countries. Of these 10 countries, the logistics performance ranking of five countries was calculated as below the original ranking and that of five countries was calculated as higher. The difference in the rankings of the 10 countries was quite small (one or two places).

According to the performance ranking made using the proposed method, the first five countries are Germany, Canada, Japan, France, and the USA. However, according to the

original LPI score, the top five countries are Germany, Canada, France, Japan, and Korea. As can be seen, the ranking found is very similar to the original LPI ranking.

With the cluster analysis, it was determined that the countries could be collected into three homogeneous clusters. It was observed that the countries in the first cluster were in the top 11 according to both TOPSIS analysis and World Bank LPI scores. It was determined that the countries in the second cluster were the last four countries according to TOPSIS and LPI values. It was observed that countries with medium performance levels were gathered in the third cluster.

This study's results significantly overlap with the results obtained by Ulkhaq [29], Ulutas and Karakoy [17], Orhan [19], and Turkoglu and Duran [18]. The results obtained in these studies using 2018 data were very close to the World Bank LPI ranking. While Turkoglu and Duran [18] and Ulutas and Karakoy [17] argued that the top three countries with the highest logistics performance rankings are Germany, Japan, and the United Kingdom; Orhan [19] stated that Germany, Sweden, and Denmark are in the top three. In our study with 2023 data, Germany, Canada, and Japan were found to be the top three. The clustering made by Ulkhaq [29] is similar to the clustering result in our study. The reason why the study results differ slightly is due to the differences in the methods used and the data year taken as a basis.

The strong similarity of the ranking we calculated with both the original LPI ranking and other studies is an important sign of the effectiveness of the method used in this study.

7. Conclusions

In this study, TOPSIS analysis was conducted using the customs score, infrastructure score, logistics adequacy and quality score, international shipment score, timeliness score, and tracking and monitoring score, which were the determinants of the LPI scores of G20 countries for 2023, and the analysis results were compared with the index scores. Then, with cluster analysis, the countries were grouped homogeneously. As a result of the analysis, it was determined that the LPI scores were similar, and the countries could be collected into the homogeneous clusters.

The findings obtained as a result of the analysis were significantly similar to the original LPI scores published by the World Bank. The five countries with the best logistics performance were found to be Germany, Canada, Japan, France, and USA, in descending order. In addition, these findings were found to be compatible with the results obtained by Ulkhaq [29], Ulutas and Karakoy [17], Orhan [19], and Turkoglu and Duran [18].

This study contains meaningful contributions both theoretically and in terms of application. First of all, it contributes to the conceptualization of logistics performance and will facilitate both the concept and measurement processes for researchers who will work in this field in the future, because this study proposes a new method. For practitioners, it will help them develop an accurate perspective on how to manage their logistics performance.

The main limitation of this study is the assumption that LPI subcomponents are of equal importance. In future studies, the analysis can be repeated by calculating the importance levels of the LPI subcomponents. In future studies, different multicriteria decision-making methods such as AHP can be used, and all countries in the LPI evaluation can be included in the analysis. Conducting the analysis with data from a single year is another limit. In future studies, the analysis can be enriched by taking more years into consideration. The results obtained with different analysis methods may be the same as the results in this study, or they may be different. Additionally, considering LPI subcomponents for more than one year in other studies will provide researchers with a broader perspective.

Our recommendations to policy makers are as follows: It is important for policy makers to take steps to remove barriers to trade and speed up shipments in order to increase logistics performance and thus revitalize international trade. Thus, shipping time can be shortened, and efficiency can be increased. In addition, increasing investments in transportation infrastructures increase logistics performance and stimulate exports and therefore economic growth. Investments made in developing logistics infrastructures

will also positively affect the economic growth of countries. It is clear that these policy recommendations are difficult to implement in the short term and will impose a significant financial burden. However, considering the long-term benefits, it is thought that efforts to increase logistics performance should be taken into consideration by policy makers.

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