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Research Article

Ranking of Metropolitan Airports Using CRITIC-Based MOORA Method

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Abstract
Air transportation plays a vital role in commercial and cultural interactions by minimizing transit time losses. Airport capacities have become a strategic advantage and a competitive factor among nations. In recent years, significant investments have been made in air transportation in our country, particularly in provinces previously lacking airports, to enhance interregional trade and cultural exchange while promoting balanced economic development.
This study evaluates the performance of 28 metropolitan airports using 2024 data and four criteria. The CRITIC method was applied to determine criterion weights, revealing close importance levels (0.300–0.186). The MOORA method was then used to rank the airports based on these weights. As a result, airports in major cities like Istanbul, Ankara, and Antalya ranked highest, while those in Tekirdağ, Hatay, and Eskişehir ranked lowest. The findings highlight the impact of urban population density and infrastructure on airport performance.

Keywords: Multi criteria decision making, MOORA, CRITIC, airports
JEL Classification Codes: C39, C60, C61

CRITIC Tabanlı MOORA Yöntemi Kullanılarak Büyükşehir Havaalanlarının Sıralanması

Öz
Hava taşımacılığı, transit zaman kayıplarını en aza indirerek ticari ve kültürel etkileşimlerde hayati bir rol oynamaktadır. Havaalanı kapasiteleri stratejik bir avantaj ve ülkeler arasında bir rekabet unsuru haline gelmiştir. Son yıllarda ülkemizde, özellikle daha önce havalimanı bulunmayan illerde, bölgeler arası ticareti ve kültürel alışverişi artırmak ve dengeli ekonomik kalkınmayı teşvik etmek amacıyla hava taşımacılığına önemli yatırımlar yapılmaktadır.
Bu çalışmada, 2024 yılı verileri ve dört kriter kullanılarak 28 büyükşehir havalimanının performansı değerlendirilmiştir. Kriter ağırlıklarını belirlemek için CRITIC yöntemi uygulanmış ve birbirine yakın önem seviyeleri (0,300-0,186) ortaya çıkmıştır. Daha sonra havalimanlarını bu ağırlıklara göre sıralamak için MOORA yöntemi kullanılmıştır. Sonuç olarak, İstanbul, Ankara ve Antalya gibi büyük şehirlerdeki havalimanları en üst sırada yer alırken, Tekirdağ, Hatay ve Eskişehir'deki havalimanları en alt sırada yer almıştır. Bulgular, kentsel nüfus yoğunluğu ve altyapının havalimanı performansı üzerindeki etkisini vurgulamaktadır.

Anahtar kelimeler: Çok kriterli karar verme, MOORA, CRITIC, havalimanları
Jel Sınıflandırma Kodları: C39, C60, C61

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1. Introduction

The activity of transporting produced goods and services, people, or living creatures from one place to another using various vehicles is called transportation. Just as goods and services have developed in every field in parallel with the development of human history, transportation activities have also developed to the same extent. Today, these activities have spread to wide areas and have diversified. In this diversity, people have given priority to what is fast, reliable, and comfortable. Air transportation has become the most preferred means of transportation in terms of speed and comfort, especially in reaching long distances.

For countries, air transportation is important in terms of economy, trade, and cultural activities, especially tourism. As stated in the airline sector analysis report (2019), air transportation, which is the main factor in developing trade and reducing poverty, is more environmentally friendly compared to other transportation sectors. Considering that speed and distance are important, especially in the field of health services, the importance of airline investments has increased. Therefore, air transportation has become an indicator of the development level of a country. It forms the basis for major developments in the commercial and military fields, especially with the development of new technologies.

There have been great developments in this field in our country in the past 20 years. With the investments made, before 2003, domestic flights could be made from 2 centers to 26 destinations. Turkey has written a success story in civil aviation in the past 22 years that has amazed the world. With 57 airports, 343 domestic and international flight destinations, and the number of passengers reaching 214 million, Turkish civil aviation has become one of the most important actors in global aviation not only in its region but also around the world. Türkiye not only known for its growth figures in civil aviation; it is set as an example all over the world with its compliance with international aviation standards and service quality. (Airline Industry Report, 2023). Especially with the investments made in the eastern and southeastern provinces, which previously did not have air transportation, the economic imbalance was tried to be eliminated, and it was aimed to increase trade and tourism (Sarılgan, 2011; Özdağoğlu et al., 2021). In this study, 28 airports located in metropolitan areas were compared. CRITIC- based MOORA method was used in the study.

2. Literature and Method

Many studies have been conducted with the CRITIC and MOORA methods used in the study. There are studies in which both alternatives are ranked and criteria are weighted using the CRITIC method. Some examples of these studies are presented in Table 1.

Table 1: Literature Summary

Methods	Study	Writer
CRITIC	An Application on Weighting	(Diakoulaki et al., 1995)
CRITIC	Air Conditioner Selection	(Vujıcic et al., 2017)
CRITIC-MOOSRA	UPS Selection	(Demircioğlu and Coşkun, 2018)
CRITIC and EVAMIX	Choosing a Laptop	(Ulutaş and Cengiz, 2018)
CRITIC-TOPSIS	Criterion Weighting	(Arslan. 2019)
CRITIC-TOTAL MOORA	Performance Evaluation	(Özmen et al., 2024)
CRITIC-WASPAS	Ranking	(Ghorabaee et al., 2017)
CRITIC BASED WASPAS	Ranking of Airports	(Arslan, 2021)
CRITIC and WASPAS CRITIC Based MULTIMOORA and TOPSIS	Smartphone Selection Financial Performance Analysis	(Demir and Kartal, 2020) (Süslü and Hızlıer, 2023)

In addition to multi-criteria decision-making techniques, efficiency and productivity methods such as data envelopment analysis and total factor efficiency have also been used in evaluating the performance of airports (Gökdalay and Evren, 2009). In his study, Ar (2012) examined the efficiency variability of state airports between 2007 and 2011, and in this study, she used the Malmquist-Total Factor Productivity (TFP) Index method. Kıyıldı and Karaşahin (2009) listed 32 airports using the data envelopment method and commented on their effectiveness. Adler and Berechmen (2001) examined the quality and efficiency of large-capacity airports in Western Europe using the data envelopment analysis method and revealed the harmony and contribution of these airports to flight networks. Yeh and Kuo (2003) used the optimality approach, one of the fuzzy decision-making methods, in their airport evaluation study of passengers.

2.1. Method

MCDM refers to making choices among alternatives in environments where there are multiple and often conflicting criteria. In choices to be made among alternatives with more than one different criteria, the importance level of the existing criteria is the most important factor affecting the decision. Objective and subjective methods can be used for criterion weighting in decision problems (Arslan, 2020).

The data of the 28 metropolitan airports listed in the research were first weighted with the CRITIC method, and these weight values were integrated into the MOORA method, and the alternatives were ranked. The theoretical knowledge of these methods is briefly mentioned.

2.1.1. CRITIC Method

One of the most important stages in the decision problem is the correct assignment of the importance levels of the criteria (Tervonen et al. 2009). The purpose of determining the importance levels of the criteria is to determine their impact levels on the decision to be made.

The most distinctive feature of the CRITIC method is that it is based on an objective weighting basis. What makes this method objective is that it is based on the correlation between criteria in weighting (Ghorabaee et al., 2018). In addition, each criterion also includes its own standard deviation in its weight. Thanks to the correlation between criteria, the contrasts of the criteria are detected, and these contrasts are weighted with the standard deviation. In this way, criteria are weighted without the need for subjective opinions of the decision maker and other participants.

The solution steps of this method can be briefly expressed as follows (Diakoulaki et al. 1994; Demir et al., 2021):

Step 1: Consider a decision problem with m alternatives and n criteria. f^* and f^- values j. Normalized values are calculated with the following function to show the best and worst values for the criterion, respectively;

$$r_{ij} = \frac{x_{ij} - f_j^{min}}{f_j^{maks} - f_j^{min}} \text{ (for benefit criteria)} \quad (1)$$

$$r_{ij} = \frac{f_j^{maks} - x_{ij}}{f_j^{maks} - f_j^{min}} \text{ (for cost criteria)} \quad (2)$$

Step 2: Let the correlation coefficient between the criterion values (columns) in the normalized decision matrix be denoted by l_{kj}j. Then j. contrast between criterion and criteria;

$$\sum_{k=1}^{n} \left(1 - l_{kj}\right) \quad (3)$$

It is given by the formula.

Step 3: In decision problems, the information contained in the decision matrix is related to the intensity of the contrast between the criteria. Therefore, the amount of information C_j spread in the jth criterion is expressed by the following multiplicative integration formula:

$$C_j = \sigma_j \sum_{k=1}^{n} (1 - l_{kj}) \quad (4)$$

As can be seen from the equations, since a higher C_j value indicates a higher amount of information, the relative importance, that is, the weight value, of the relevant criterion is also high. Therefore, the high level of knowledge is mainly due to two differences. One of these is the variance value of the criterion itself (σ_j), and the other is the correlation between the criterion and other criteria (l_{kj}). As the variance value within the criterion increases, the level of information increases.

Step 4: Objective weights are presented with the following normalization formula (Diakoulaki et al. 1994);

$$w_j = \frac{c_j}{\sum_{k=1}^{n} c_k} \tag{5}$$

w_j value is the ratio of C_j values of each criterion to the total C_j value. In this way, the sum of the criterion weights becomes 1. The criterion with the highest value is the feature that provides the most information and therefore has the highest level of importance.

2.1.2. MOORA Method

The Multi-Objective Optimization on the Basis of Ratio Analysis (MOORA) method was introduced by Willem Karel M. Brauers and Edmundas Kazimieras Zavadskas in their article titled "The MOORA Method and Its Application to Privatization in a Transition Economy," published in 2006 (Önay and Çetin, 2012). MOORA, a novel approach designed for multi-objective optimization with discrete alternatives, represents the matrix of responses of the alternatives based on the objectives for which ratios are applied (Arslan ve Bircan, 2018).

Compared to other multi-criteria decision-making techniques, the MOORA method is more advantageous due to its shorter calculation time, simplicity, reduced mathematical complexity, reliability, and flexibility regarding the types of data used in analysis. The MOORA method is divided into two fundamental components: the ratio system and the reference point approach (Şimşek et al., 2015). Research has demonstrated that the MOORA method outperforms other multi-criteria decision-making techniques in terms of mathematical efficiency, stability, and the range of data types it accommodates. The application steps of the MOORA method are as follows (Kundakçı, 2016):

Ratio method: a decision matrix is created where i= 1, 2, … m is the number of alternatives, j= 1, 2, … n is the number of criteria.

$$X = \begin{bmatrix} x_1(1) & \cdots & x_1(n) \\ \vdots & \ddots & \vdots \\ x_m(1) & \cdots & x_m(n) \end{bmatrix} \tag{6}$$

The normalization matrix is obtained by dividing the criteria by the square root of the sum of the squares of each alternative. This process,

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \quad (7)$$

It is obtained by Eq. x_{ij}^{*}; i. Your alternative, j. It is the normalized version of the value for the criterion.

After the normalization process, the criteria in each column are assessed and summed based on whether they are to be maximized or minimized. The total values of the minimized criteria are then subtracted from the total values of the maximized criteria. In summary, this calculation can be expressed as follows, where

j=1,2,3,…,g j=1,2,3,…,g represents the criteria to be maximized, and i=1,2,3,…, n. i=1,2,3,…,n represents the criteria to be minimized:$y_i^{*}=\sum_{j=1}^{g} x_i^{*} - \sum_{j=g+1}^{n} x_i^{*}$ can be shown as.

3. Findings

28 airports located in metropolitan regions constitute the alternatives of this study. The alternatives used in the study and their abbreviations in the calculations are given in Table 2.

Table 2: Airport Codes and Names

Code	Airport	Code	Airport
A1	İstanbul (*)	A15	Denizli Çardak
A2	İstanbul Sabiha Gökçen (*)	A16	Diyarbakır
A3	Ankara Esenboğa	A17	Eskişehir Hasan Polatkan (*)
A4	İzmir Adnan Menderes	A18	Hatay
A5	Antalya	A19	Kahramanmaraş
A6	Gazipaşa Alanya (*)	A20	Kayseri
A7	Muğla Dalaman	A21	Konya
A8	Muğla Milas-Bodrum	A22	Malatya
A9	Adana	A23	Mardin Prof. Dr. Aziz Sancar
A10	Trabzon	A24	Ordu-Giresun
A11	Erzurum	A25	Samsun Çarşamba
A12	Gaziantep	A26	Şanlıurfa Gap
A13	Balıkesir Koca Seyit	A27	Tekirdağ Çorlu Atatürk
A14	Bursa Yenişehir	A28	Van Ferit Melen

Four main criteria were used to rank the alternatives. These criteria and the codes used in the calculation are presented in Table 3.

Table 3: Criteria and Codes of Alternatives

Criterion Code	Criterion Direction	Criterion Name	Measurement Unit
K1	Benefit	All aircraft	Landing-takeoff
K2	Benefit	Traveller	Number of people
K3	Benefit	Cargo	Landing-takeoff
K4	Benefit	Load	Ton

Table 3 lists the characteristics of the alternatives used in the evaluation. Brief definitions of these features can be summarized as follows (Özdağoğlu et al., (2021). All aircraft: The total number of aircraft traffic arriving and departing from the airport. Traveller: Persons other than personnel who travel by plane from the airport. Cargo: The number of landings and takeoffs of airport cargo planes. Load: It is the weight of items such as documents and cargo carried by planes. The criterion values of the evaluated alternatives are presented in Table 4. These values were used in the calculations.

Table 4: Initial Decision Matrix

Alternative	K1	K2	K3	K4
A1	40120	6001619	144925	249557
A2	18801	3155053	4270	31763
A3	6669	984456	682	9397
A4	4681	738670	2371	9705
A5	7047	1002729	455	10872
A6	368	45582	0	408
A7	530	77722	3	610
A8	603	91415	12	663
A9	2649	416134	301	4092
A10	1428	216840	67	1842
A11	593	106546	5	971
A12	1356	223447	93	2115
A13	87	9904	1	92
A14	113	19125	0	232
A15	275	38526	38	359
A16	975	169613	89	1486
A17	52	8437	0	175
A18	60	7440	0	72
A19	109	15466	4	134
A20	1309	190519	72	2030
A21	534	78481	26	856

A22	386	63037	21	462
A23	385	65688	17	578
A24	551	84615	39	686
A25	805	121462	30	1131
A26	416	67474	12	573
A27	22	2284	6	22
A28	820	139270	74	1306

3.1. CRITIC Method Findings

Using the starting matrix in Table 4, the criteria were first weighted with the CRITIC method. First, the initial matrix was normalized according to the CRITIC method rule and the resulting normalized matrix is presented in Table 5.

Table 5: CRITIC Method Normalized Matrix

	K1	K2	K3	K4
A1	1,0000	1,0000	1,0000	1,0000
A2	0,0295	0,1272	0,5255	0,4683
A3	0,0047	0,0376	0,1637	0,1658
A4	0,0164	0,0388	0,1227	0,1162
A5	0,0031	0,0435	0,1668	0,1752
A6	0,0000	0,0015	0,0072	0,0086
A7	0,0000	0,0024	0,0126	0,0127
A8	0,0001	0,0026	0,0149	0,0145
A9	0,0021	0,0163	0,0690	0,0655
A10	0,0005	0,0073	0,0358	0,0351
A11	0,0000	0,0038	0,0174	0,0142
A12	0,0006	0,0084	0,0369	0,0333
A13	0,0000	0,0003	0,0013	0,0016
A14	0,0000	0,0008	0,0028	0,0023
A15	0,0003	0,0014	0,0060	0,0063
A16	0,0006	0,0059	0,0279	0,0238
A17	0,0000	0,0006	0,0010	0,0007
A18	0,0000	0,0002	0,0009	0,0009
A19	0,0000	0,0004	0,0022	0,0022
A20	0,0005	0,0080	0,0314	0,0321
A21	0,0002	0,0033	0,0127	0,0128
A22	0,0001	0,0018	0,0101	0,0091
A23	0,0001	0,0022	0,0106	0,0091
A24	0,0003	0,0027	0,0137	0,0132
A25	0,0002	0,0044	0,0199	0,0195
A26	0,0001	0,0022	0,0109	0,0098
A27	0,0000	0,0000	0,0000	0,0000
A28	0,0005	0,0051	0,0228	0,0199

Second step, the correlation coefficient between the criterion values (columns) in the normalized decision matrix was calculated. The correlation matrix between the obtained criteria is presented in Table 6.

Table 6: Correlation Matrix

Criteria	K1	K2	K3	K4
K1	1	,994	,881	,899
K2		1	,926	,940
K3			1	,999
K4				1

Step 3: In this step, the amount of information C_j spread in the jth criterion was calculated. For this, the equation $C_j = \sigma_j \sum_{k=1}^{n}(1 - l_{kj})$ is used. σ_j in this equation is the standard deviation of each normalized criterion. The standard deviation of each criterion in the normalized matrix is given in Table 7.

Table 7: Criterion Standard Deviations

Criteria	K1	K2	K3	K4
Standard Deviations	0,19	0,19	0,20	0,20

Step 4: After the standard deviations were calculated, the correlation value of each criterion was subtracted from 1 and summed using the equation $\sum_{k=1}^{n}(1 - l_{kj})$. Then, to calculate the w_j value, the C_j values of each criterion were compared to the total C_j value. The obtained weight values are presented in Table 8.

Table 8: Criterion Weight Values

	K1	K2	K3	K4
w_j (Weight)	0,30	0,19	0,28	0,23

As seen in Table 8, the importance levels of the criteria are calculated close to each other. Therefore, the levels of information they disclose are close to each other.

3.2. MOORA Method Findings

The importance levels obtained in Table 8 were integrated into the normalized matrix in the MOORA method and the alternatives were listed. In this context, as the first step in the MOORA method, the decision matrix was normalized and the matrix given in Table 9 was obtained.

Table 9: MOORA Method Normalized Matrix

	K1	K2	K3	K4
A1	0,999	0,989	0,858	0,876
A2	0,029	0,126	0,451	0,411
A3	0,005	0,037	0,141	0,146
A4	0,016	0,038	0,106	0,102
A5	0,003	0,043	0,143	0,154
A6	0,000	0,002	0,007	0,008
A7	0,000	0,002	0,011	0,012
A8	0,000	0,003	0,013	0,013
A9	0,002	0,016	0,059	0,058
A10	0,000	0,007	0,031	0,031
A11	0,000	0,004	0,015	0,013
A12	0,001	0,008	0,032	0,030
A13	0,000	0,000	0,001	0,002
A14	0,000	0,001	0,003	0,002
A15	0,000	0,001	0,006	0,006
A16	0,001	0,006	0,024	0,021
A17	0,000	0,001	0,001	0,001
A18	0,000	0,000	0,001	0,001
A19	0,000	0,001	0,002	0,002
A20	0,000	0,008	0,027	0,029
A21	0,000	0,003	0,011	0,012
A22	0,000	0,002	0,009	0,008
A23	0,000	0,002	0,009	0,008
A24	0,000	0,003	0,012	0,012
A25	0,000	0,004	0,017	0,018
A26	0,000	0,002	0,010	0,009
A27	0,000	0,000	0,000	0,000
A28	0,001	0,005	0,020	0,018

Relative importance values were calculated by integrating the criterion weights obtained with the CRITIC method into the normalized matrix. The obtained values are given in Table 10.

Table 10: MOORA Method Weighted Normalized Matrix

	K1	K2	K3	K4
A1	0,300	0,184	0,243	0,203
A2	0,009	0,023	0,128	0,095
A3	0,001	0,007	0,040	0,034
A4	0,005	0,007	0,030	0,024

A5	0,001	0,008	0,041	0,036
A6	0,000	0,000	0,002	0,002
A7	0,000	0,000	0,003	0,003
A8	0,000	0,000	0,004	0,003
A9	0,001	0,003	0,017	0,013
A10	0,000	0,001	0,009	0,007
A11	0,000	0,001	0,004	0,003
A12	0,000	0,002	0,009	0,007
A13	0,000	0,000	0,000	0,000
A14	0,000	0,000	0,001	0,001
A15	0,000	0,000	0,002	0,001
A16	0,000	0,001	0,007	0,005
A17	0,000	0,000	0,000	0,000
A18	0,000	0,000	0,000	0,000
A19	0,000	0,000	0,001	0,001
A20	0,000	0,001	0,008	0,007
A21	0,000	0,001	0,003	0,003
A22	0,000	0,000	0,003	0,002
A23	0,000	0,000	0,003	0,002
A24	0,000	0,001	0,003	0,003
A25	0,000	0,001	0,005	0,004
A26	0,000	0,000	0,003	0,002
A27	0,000	0,000	0,000	0,000
A28	0,000	0,001	0,006	0,004

In the 4th step, the total values of the criteria were calculated according to the MOORA method and their rankings are given in Table 11.

Table 11: MOORA Total Values and Ranking

	MOORA Total	Rank
A1	0,929	1
A2	0,255	2
A3	0,082	4
A4	0,066	5
A5	0,085	3
A6	0,004	21
A7	0,006	17
A8	0,007	14
A9	0,034	6
A10	0,017	8
A11	0,008	13
A12	0,018	7

A13	0,001	25
A14	0,002	23
A15	0,003	22
A16	0,013	10
A17	0,001	26
A18	0,001	27
A19	0,001	24
A20	0,016	9
A21	0,007	16
A22	0,005	20
A23	0,005	19
A24	0,007	15
A25	0,010	12
A26	0,005	18
A27	0,000	28
A28	0,011	11

As seen in Table 11, Istanbul Airport with the highest total value, ranked first. Additionally, Istanbul Sabiha Gökçen Airport ranked second, Antalya Airport ranked third, and Ankara Esenboğa Airport ranked fourth. In addition, Tekirdağ Çorlu Atatürk Airport ranked twenty-eighth, thus ranking last in terms of performance. Hatay Airport ranked twenty-seventh and Eskişehir Hasan Polatkan Airport ranked twenty-sixth.

4. Result and Evaluation

In order for all activities in the service and production sectors to be carried out efficiently, it is necessary to clearly determine the goals and objectives and to create clear decisions and plans in line with these goals and targets. In order to maintain efficiency, all activities must be constantly monitored and evaluated, and improvements must be made. The aviation sector, which is the largest market among the service and production sectors, is the most important type of activity in which these principles should be applied. Large investments have been made in air transportation in our country in the last 20 years. Large airport investments have been made, especially in order to eliminate development inequality in all regions and to ensure economic and cultural development.

In this study, the performance ranking of 28 airports operating in the metropolitan regions of our country was made. The total of 12-month data for 2024 was used in the study. The total number of aircraft, number of passengers, number of commercial aircraft, and cargo amounts of 20 airports were taken as criteria. CRITIC and MOORA methods, which are multi-criteria decision-making techniques, were used in the evaluation. First, the criteria were weighted with the CRITIC method, which is an objective weighting model. The importance levels of the four criteria were found to be close to each other, and it was concluded that they made similar contributions to the decision output. Weight values were integrated into the MOORA method, and alternatives were ranked by the MOORA method.

Istanbul Airport ranked first. Additionally, Istanbul Sabiha Gökçen Airport ranked second, Antalya Airport ranked third, and Ankara Esenboğa Airport ranked fourth. In addition, Tekirdağ Çorlu Atatürk Airport ranked twenty-eighth, thus ranking last in terms of performance. Hatay Airport ranked twenty-seventh, and Eskişehir Hasan Polatkan Airport ranked twenty-sixth.

As a result of the ranking, Istanbul Airport ranked first among the 28 airports operating in the metropolitan regions. Istanbul Sabiha Gökçen Airport ranked second, Antalya Airport ranked third, and Ankara Esenboğa Airport ranked fourth. Tekirdağ Çorlu Atatürk Airport ranked twenty-eighth, thus ranking last in terms of performance. Hatay Airport ranked twenty-seventh and Eskişehir Hasan Polatkan Airport ranked twenty-sixth. It can be said that Istanbul, Ankara, Antalya, Adana, and Konya airports are in the first place due to their high population and industry. Similarly, airports such as Tekirdağ, Eskişehir, Balıkesir, and Kahramanmaraş ranked last.

In future studies, both different performance evaluation methods and different criterion values can be used. Performance comparisons can be made using more alternative airports.

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