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February 6, Based in Kahramanmaraş Impact of Earthquake on the Performance of Airports in the Region*

6 Şubat Kahramanmaraş Merkezli Depremin Bölgedeki Havalimanları Performanslarına Etkisi

***Tunahan AVCI*[1]** ***Muhammed Osman İLKEL*[2]**

Highlights

- *The impact of the February 6 earthquake on airports located in the disaster area was examined.*
- *Number of personnel, airport expenses and terminal area were used as input variables, while number of passengers, total number of flights and freight traffic were used as output variables.*
- *It was determined that the efficiency of the airport decreased in 2023, when the earthquake occurred.*

Abstract

The February 6 Kahramanmaraş-centered earthquakes, which occurred in our country in 2023 and are referred to as the "disaster of the century", have inevitably had an impact on airports. The impact of the earthquake was felt more especially in airports located in the disaster area. The study aimed to determine the impact of the February 6 Kahramanmaraş-centered earthquake on the performance of airports located in the disaster area. For this purpose, Hatay, Kahramanmaraş, Adana, Gaziantep, Adıyaman, Malatya, Elazığ, Şanlıurfa and Diyarbakır airports were included in the study. In this study, where the efficiency and productivity of airports were measured using the data envelopment method and Malmquist total factor efficiency indices, data for the periods 2021, 2022 and 2023 were considered. In addition, the number of personnel, airport expenses and terminal area were included in the analysis as input variables; while the number of passengers, total number of flights and freight traffic were included in the analysis as output variables. In the analyzes carried out, it was determined that a total of 6 airports were active in 2021 and 2022, while a total of 4 airports were active in 2023, when the earthquake occurred. In addition, it was concluded that the highest efficiency in 2022 was Diyarbakır Airport, the lowest efficiency was Kahramanmaraş Airport, and the highest efficiency in 2023 was Adıyaman Airport and the lowest efficiency was Hatay Airport.

Keywords	Earthquake, airport, data envelopment analysis, efficiency, productivity
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February 6, Based in Kahramanmaraş Impact of Earthquake on the Performance of Airports in the Region

Tunahan AVC[1] *Muhammed Osman İLKEL*[2]

Öne Çıkanlar

- *6 Şubat depreminin afet bölgesinde bulunan havalimanlarının üzerindeki etkisi incelenmiştir.*
- *Personel sayısı, havalimanı giderleri ve terminal alanı girdi değişkenleri olarak; yolcu sayısı, toplam uçuş sayısı ve yük trafiği ise çıktı değişkenleri olarak kullanılmıştır.*
- *Depremin meydana geldiği 2023 yılında havalimanının etkinliğinin düştüğü tespit edilmiştir.*

Öz

Ülkemizde 2023 yılında yaşanan ve ''asrın felaketi'' olarak tabir edilen 6 Şubat Kahramanmaraş merkezli depremlerin havalimanlarına etkisi kaçınılmaz olmuştur. Özellikle afet bölgesinde yer alan havalimanlarında depremin etkisi daha çok hissedilmiştir. Çalışmada, Kahramanmaraş merkezli 6 Şubat depreminin afet bölgesinde bulunan havalimanlarının üzerindeki etkisini saptamak amaçlanmıştır. Bu amaç doğrultusunda, Hatay, Kahramanmaraş, Adana, Gaziantep, Adıyaman, Malatya, Elâzığ, Şanlıurfa ve Diyarbakır havalimanları çalışmaya dahil edilmiştir. Veri zarflama yöntemi ve Malmquist toplam faktör verimliliği endeksleri kullanılarak havalimanlarının etkinlik ve verimliliklerinin ölçüldüğü bu çalışmada 2021, 2022 ve 2023 dönemlerine ait veriler ele alınmıştır. Ayrıca personel sayısı, havalimanı giderleri ve terminal alanı girdi değişkenleri olarak; yolcu sayısı, toplam uçuş sayısı ve yük trafiği ise çıktı değişkenleri olarak analiz kapsamına dahil edilmiştir. Gerçekleştirilen analizlerde, 2021 ve 2022 yıllarında toplam 6 havalimanının etkin olduğu görülürken depremin meydana geldiği 2023 yılında ise toplam 4 havalimanının etkin olduğu tespit edilmiştir. Ayrıca 2022'de en yüksek verimliliğin Diyarbakır Havalimanı, en düşük verimliliğin Kahramanmaraş Havalimanı olduğu, 2023'te ise en yüksek verimliliğin Adıyaman Havalimanı, en düşük verimliliğin ise Hatay Havalimanı olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler	Deprem, Havalimanı Veri Zarflama Analizi, Etkinlik, Verimlilik
Makale Künyesi	Avcı, T. & İlkel, M. O. (2025). February 6, based in Kahramanmaraş impact of earthquake on the performance of airports in the region. *Urban 21 Journal, 3*(2), 19-

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Introduction

The aviation sector is a significant transportation sector that has developed rapidly since the past. One of the primary reasons for this development is the fact that air travel is preferred more than other modes of transportation. Increasing demand has led to more flights and the transportation of more cargo and passengers. The two most important elements that enable these flights and transportation are airlines and airports. Airlines aim to transport passengers and cargo from one point to another in the safest and fastest way, adhering to aviation safety and regulations. Today, there are more than 5,000 airlines worldwide. The large number of airlines has also paved the way for a competitive environment. Therefore, the adoption of a liberal economy in air transportation and the implementation of different pricing policies have led to increased passenger demand. With increasing passenger demand, airport utilization capacity has increased, and airports have become one of the most frequented transportation hubs, becoming an indispensable part of aviation.

Airports are crucial for civil aviation. Because they are among the primary infrastructure factors required for air transportation. Furthermore, airports can be defined as areas where ground-based air transportation services are provided, effectively serving as a bridge between air and ground transportation. Airports are service providers that carry out various air transportation activities. The use of airports is essential for air transportation. Therefore, without an airport, it would be impossible to land and take off an aircraft, or to carry out flight transfers of passengers, baggage, and cargo without a passenger terminal (Kuyucak Şengür, 2018, s. 5).

The February 6 earthquake affected many areas and sectors in our country, including aviation and, consequently, airports. This impact is particularly evident in airports located in earthquake-prone areas. It is crucial for airport management to identify performance changes at these airports, both before and after the earthquake. This will allow us to determine the extent of the earthquake's impact.

Airports are venues that serve passengers and aircraft with their terminals, runways, aprons, towers, electronic equipment, and personnel. Airports are extremely important revenue streams, especially for developing countries. The limited resources and resulting foreign trade deficits experienced by developing countries can put them in a difficult position and cause economic hardship. Managing airports with sound strategies will significantly contribute to addressing this gap. Because our country is also a developing country, the effective and efficient operation of airports is crucial. Airports, especially those with high operating costs, must be operated effectively and efficiently to generate profits. This efficiency should be measured at regular intervals to determine their performance, and strategies should be developed based on the results obtained (Kıyıldı & Karaşahin, 2006, p. 391). The change in airport efficiency and productivity becomes even more significant during extraordinary circumstances such as epidemics and earthquakes. This is because significant decreases or increases in performance can occur compared to normal periods.

On February 6, 2023, Turkey experienced two major earthquakes, its worst disaster in recent years. The first occurred in the morning hours (04:17), with a magnitude 7.7 (Mw) earthquake centered in Pazarcık. Approximately nine hours later, at approximately 13:24, another devastating earthquake, this time with an epicenter in Elbistan and a magnitude 7.6 (Mw), struck. AFAD officials announced that at least 11,000 aftershocks followed the two major earthquakes. The earthquakes caused significant loss of life and property, primarily in Kahramanmaraş, the epicenter, and in the surrounding provinces of Hatay, Adana, Gaziantep, Adıyaman, Malatya, Elazığ, Şanlıurfa, Diyarbakır, Kilis, and Osmaniye. As a result of this disaster, which affected many of our cities, it has been determined that at least 53,000 people lost their lives and more than 107,000 were injured. In addition to the loss of life, hundreds of thousands of buildings were also destroyed by the earthquake. Post-earthquake inspections determined that approximately 264,000 buildings were destroyed or severely damaged, while at least 43,000 sustained moderate damage. In addition to damage to buildings and homes, large-scale structures such as airports, highways, bridges and crossings, industrial plants, energy supply lines, water lines, and infrastructure facilities were also damaged (TMMOB İnşaat Mühendisleri Odası, 2023, p. 1).

The earthquake particularly negatively impacted airports in the disaster area. Hatay Airport's runway collapsed and cracked, preventing it from operating for an extended period during the earthquake and remaining closed. Malatya Airport's terminal building was damaged, and passenger flights were suspended for a period, allowing only freight traffic. Kahramanmaraş and Gaziantep airports were also briefly closed to flights due to the damage (Rakipoğlu, 2024, p. 43).

Comparing the efficiency and productivity performance of airports after a disaster that severely impacted them compared to previous periods is crucial. Therefore, this study examines the extent to which nine airports operating in the earthquake zone (Hatay, Kahramanmaraş, Adana, Gaziantep, Adıyaman, Malatya, Elazığ, Şanlıurfa, and Diyarbakır) were affected by the February 6 Kahramanmaraş earthquake. Accordingly, the data envelopment method was used for airport efficiency analysis, while Malmquist total factor productivity indices were used for efficiency analysis. The analysis was conducted using annual data from the airports for the periods 2021, 2022, and 2023. In the analysis, passenger numbers, total flights, and freight traffic were used as input variables, while personnel, airport expenses, and terminal area were used as output variables.

1. February Earthquake Centered in Kahramanmaraş

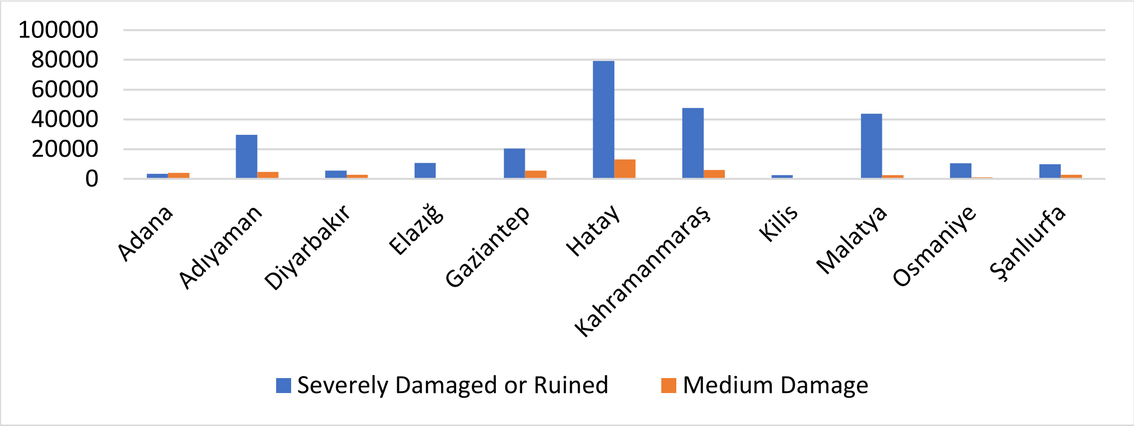
An earthquake is defined as the phenomenon where the energy released by the fracturing of the Earth's crust due to tectonic forces or volcanic activity propagates in the form of seismic waves, powerfully shaking the environments and the Earth's surface through which they pass (Afet ve Acil Durum Yönetimi Başkanlığı, 2014, p. 58). The dynamic interaction of tectonic plates causes stress accumulation. For this stress to be expressed, it must grow sufficiently. As a result of this growth, tears occur in the outer sediment. These tears continue along the fault lines. Stresses that have reached sufficient levels generate intense energy and emit vibration waves, creating tremors in the Earth's surface. This tremor is called an earthquake (Darılmaz, 2019, p. 2).

The occurrence of an earthquake generally depends on the movement of flexible fault lines. Flexible fault lines are called faults. Intense energy accumulates on the fault line, and after a certain level, this energy causes slippage along the fault line, creating an earthquake. Therefore, an earthquake is an event that occurs as a result of a chain reaction of natural movements and produces a powerful tremor in the affected region (Işık, 1992, p. 102). An earthquake is the sudden release of elastic energy, which has accumulated intensely in the upper layers of the Earth for many years, causing tremors in the upper layers of the Earth. The primary cause of this energy accumulated in the upper layers of the Earth is the high temperature and compression forces in the lower layers of the Earth (Demirtaş & Erkmen, 2000, p. 1).

Two major earthquakes occurred in two districts of Kahramanmaraş, Turkey, on February 6, 2023. The first of these occurred at 4:17 AM, centered in Pazarcık, with a magnitude of 7.7. The second, centered in Elbistan, occurred approximately nine hours later, at 1:24 PM, with a magnitude of 7.6. The magnitude of the disaster was so great that it caused widespread destruction in nearly all surrounding provinces. The earthquake's intensity destroyed buildings, resulting in deaths and injuries, in Adana, Hatay, Adıyaman, Malatya, Gaziantep, Elazığ, Osmaniye, Diyarbakır, Kilis, and Şanlıurfa. An examination of official records indicates that 53,537 people lost their lives as a result of this disaster of the century, 107,213 were injured, 263,123 buildings were collapsed or severely damaged, and 43,344 buildings sustained moderate damage. This earthquake, also known as the disaster of the century, directly affected 11 cities and at least 14 million people living in these cities. Furthermore, it has caused significant damage to the environmental order, infrastructure and superstructure, structural regions, the national economy, social life, and public administration (Türkiye Belediyeler Birliği, 2024, p. 5).

Chart 1.

Number of building damages by city as a result of the February 6 earthquake



Reference: Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2024

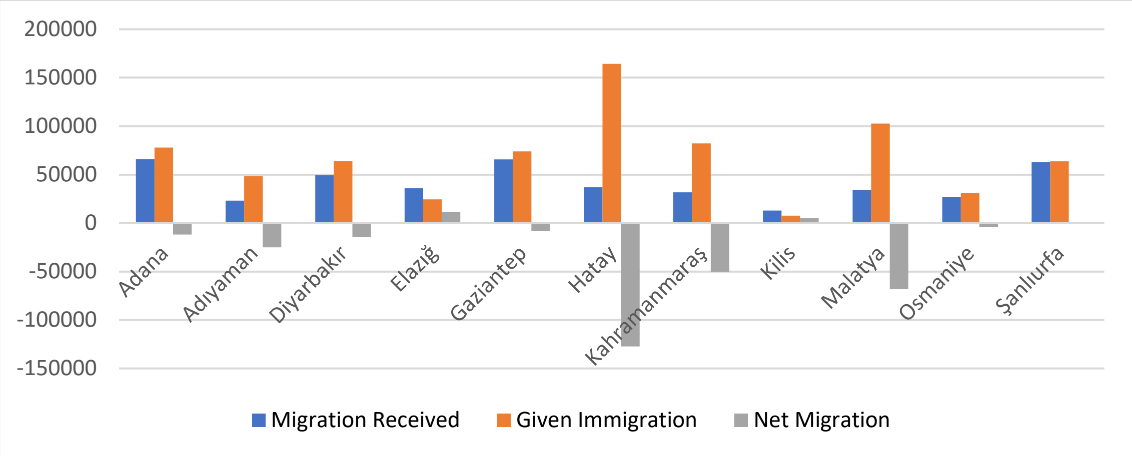
Chart 1 shows the number of buildings affected by the earthquake in 11 provinces, including those with severe damage, collapse, and moderate damage. As can be seen, the February 6, 2023, earthquake had a devastating impact in all 11 provinces. Thousands of buildings were destroyed, severely damaged, or moderately damaged. Although the epicenter was Kahramanmaraş, it can be concluded that Hatay had the highest number of damaged buildings in the province. Nearly 80,000 buildings in Hatay were either collapsed or severely damaged. The February 6 earthquake, centered in Kahramanmaraş, like other disasters, had numerous regional and public consequences. Its social and economic impacts, in particular, were felt nationwide, leading to changes and transformations in many areas, from demographics to public investments and expenditures. These will be examined in detail.

1.1. The social dimension of the February 6 Earthquake

The most significant social impact of earthquakes is that they are disasters that force people to migrate. After the February 6 earthquakes caused destruction in 11 provinces, earthquake victims living in the region migrated to other cities they considered safe. Analysis of the initially shared data revealed that nearly 2.7 million earthquake victims were displaced from the earthquake zones to other regions. These people may settle temporarily or permanently in the provinces they chose for safety and health reasons. Therefore, considering the post-earthquake period, it appears that a significant number of people became homeless and were forced to migrate. This intense internal migration creates problems both in the earthquake zones and in other regions to which they migrated. The impact of migration from earthquake zones reduces the labour force needed for the region's development. Furthermore, the rapid population growth in the cities to which they migrated leads to an uneven distribution of the population. In addition, there is an increase in rents due to the intense demand for housing in the region receiving immigration, and the search for employment due to the increase in the workforce in the region of immigration remains fruitless (Tiryaki Yenilmez, 2023, pp. 48-49).

Chart 2.

Chart of immigration, out-migration and net immigration of 11 cities for 2023



Reference: TÜİK, 2023

An examination of Chart 2 reveals that almost all disaster-affected provinces out-migrated more than they received. Therefore, net migration rates were negative. It can be seen that Hatay, Malatya, and Kahramanmaraş, in particular, experienced high levels of migration. It is also possible to infer that Hatay was the earthquake-affected province with the highest rate of migration. Contrary to the general trend, Kilis and Elazığ provinces exhibited positive net migration results due to their higher in-migration.

Education is another issue that emerged from the impact of the February 6 earthquakes. International institutions and organizations emphasize the importance of resuming education after meeting basic needs in emergencies such as earthquakes, floods, and wars. In some regions, education resumed as of March 1, 2023. However, in other regions, education activities were disrupted, and educational activities were not carried out for an extended period. This situation causes problems for school-aged children and youth, such as the desire to drop out, the persistence of traumatic events, and a decline in academic success. Therefore, school activities play a significant role in preventing students from experiencing additional problems and becoming antisocial in the event of a disaster (Şahin Demir, 2023, p. 9).

1.2. The economic dimension of the February 6 Earthquake

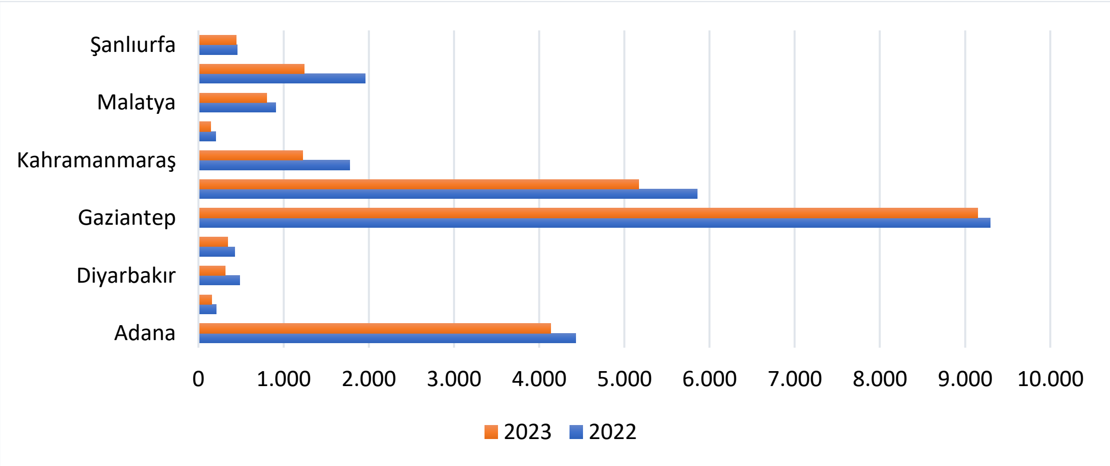
Beyond the loss of life and property, the damage earthquakes inflict on the region and national economy is also extremely significant. Therefore, identifying the impact of this damage, creating resources to cover the damage, and using this fund to rebuild the earthquake zone and improve the national economy are among the key economic steps to be taken after an earthquake. The damage inflicted by the disaster of the century on the national economy has also been immense.

Based on the assessment and investigation of the disaster areas, the earthquake's impact on Turkey's economic structure is estimated to be approximately $103.6 billion. This financial loss was determined to be approximately $85 billion in direct damage caused by the earthquake, while the remaining $18.6 billion stemmed from indirect expenses resulting from the disruption or reduction of economic activity due to the disaster. Furthermore, it was determined that residential damage, at $56.9 billion, was the largest expense item, accounting for $103.6 billion. Similarly, other expense items that resulted in significant costs were reported as $12.9 billion in losses in the public sector and $11.8 billion in losses in the private sector. Analyzing these figures, it was determined that the total cost of the earthquake was equal to approximately 9% of the national income for 2023 (Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2024, pp. 6-119).

Export-related activities play a significant role in Turkey's economy. Cities located in the earthquake zone were found to account for 10.2% of total national exports for 2022. Following the earthquake on February 6, 2023, the total export value of the disaster-affected provinces decreased by $2.9 billion. Therefore, these provinces' share of the country's total exports was 9% in 2023, representing a decrease of 1.2 percentage points. It was determined that Hatay, Kahramanmaraş, and Osmaniye were the provinces most affected by the disaster of the century in terms of exports. The decrease in export figures in the disaster area was found to be 11.1%, with these three provinces accounting for approximately 7.5% of this decrease (Türkiye Cumhuriyeti Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2024, p. 12).

Chart 3.

Share of 11 cities in foreign trade (million dollars)



When the data in Chart 3 is examined, it can be observed that export values in earthquake-hit provinces decreased in 2023 compared to the previous year. Although Gaziantep was the province with the highest exports, Hatay, Osmaniye, and Kahramanmaraş were the most affected provinces in terms of percentage.

2. Literature Review

To ensure that airports provide effective and efficient service and maintain this continuity, they must conduct performance evaluations at regular intervals, particularly during crisis periods. The analyses performed should determine whether airports are operating efficiently, and the necessary steps should be taken accordingly. A review of the literature reveals numerous studies measuring airport performance. However, this study differs from the literature in that it identifies changes in the performance of airports located in earthquake-stricken areas following the earthquake. Studies examining airport performance are reviewed and presented below.

In his study, Battal (2020) measured the financial performance of Aena, Fraport, Ferrovial, Royal Schiphol, TAV, and Aeroports de Paris, all airport operating groups operating in Europe, using the input-focused BCC model. Utilizing the data envelopment technique, this study used the financial leverage ratio and current ratio as input variables, while the return on assets ratio was used as the output variable. Furthermore, annual data from four different periods, 2015, 2016, 2017, and 2018, were examined. The analysis found that three of the airport operators included in the study were effective (Aena, Fraport, and Royal Schiphol), while three were inefficient (TAV, Aeroports de Paris, and Ferrovial).

Choi et al. (2020) aimed to measure the operational efficiency of China's 37 largest airports. This study, which used the data envelopment method, examined data from the 2016-2019 period. Terminal area and runway length were used as input variables, while total passenger numbers, total flight numbers, freight traffic, and delay rates were used as output variables. The analysis revealed that the average efficiency of the relevant airports was very low at 48.2%. They also determined that, with the exception of eight airports with constant returns to scale, such as Beijing and Guangzhou, other airports could increase their operational efficiency with additional investments.

In his study, Pehlivanlı (2020) examined data from Turkey's 20 largest airports for the first quarter of 2019-2020 using Data Envelopment Analysis and the Malmquist Total Factor Productivity Index, aiming to determine the impact of Covid-19 on the performance of these airports. The study used personnel and passenger terminal numbers as input variables, and passenger numbers, flight numbers, and freight traffic as output variables. The analysis found that even in the early stages of the crisis, airport efficiency decreased by 85%, and airport efficiency values also decreased.

Taşdemir (2020) examined changes in airport efficiency compared to the previous year to determine the impact of the Covid-19 crisis on airports. This study, which used Data Envelopment Analysis, examined Turkey's six busiest airports and included data from the first three quarters of 2019 and 2020. The study used runway number, terminal area, and aircraft parking capacity as input variables, while the number of landings and takeoffs, passenger numbers, and freight traffic as output variables. As a result of the Data Envelopment Analysis performed, it was determined that there was a sharp decrease in the activity scores with the onset of the epidemic, but with the increase in flights in the summer months, the activity values increased again and compared to the previous year, the activity values were halved.

Olariaga & Moreno (2019) used the data envelopment method to compare public and private airports by measuring performance and efficiency for 17 privately managed airports and 5 publicly managed airports in Colombia. They used the number of runways, runway length, number of aircraft parking positions, terminal area, and apron area as input variables, while the number of passengers, cargo volume, and number of flights were used as output variables. They analyzed data from 2012 to 2017 for the selected variables. Their study found that, on average over the years studied, 6 of the privatized airports increased their efficiency, while 4 decreased their efficiency. They found that 3 of the publicly managed airports increased their efficiency, while 2 decreased their efficiency. They also determined that large airports, both privately managed and publicly managed, have high efficiency.

Stichhauerova & Pelloneova (2019) conducted performance evaluations of 27 airports operating in Germany using data from 2016. They employed an input-focused approach in their study, employing the data envelopment method. In the analysis, they used the number of personnel, the number of runways, and terminal area as input variables, while the number of flights and cargo volume were used as output variables. As a result of the study, they determined that 13 airports were efficient, while the remaining 14 were inefficient.

Rabar, Zenzerovic, & Sajrih (2017) conducted performance evaluation analyses of seven airports in Croatia using the data envelopment technique. Their analysis examined the period between 2009 and 2014. In their study, total personnel costs, total expenses, and total assets constituted the input variables, while total revenues constituted the output variable. As a result of the DEA analysis, they determined that Split, Pula, and Zadar airports were efficient for four years during the periods studied, while Zagreb and Osijek airports were efficient for only one year. They also determined that Split had the highest efficiency performance, while Osijek had the lowest.

Perico, Santana, & Rebelatto (2017) aimed to measure the efficiency of 16 international airports in Brazil in their study. To this end, they used data from 2010, 2011, and 2012, applying data envelopment and multiple regression analyses. In their analysis, they used the number of runways, counters, terminal area, and aircraft parking positions as input variables, while the number of passengers served as output variables. Their study found that Curitiba Airport was the most efficient airport, while Galeao and Manaus airports were the least efficient.

Fragoudaki, Giokas, & Glyptou (2016) conducted a study to determine the impact of the major economic crisis experienced by Greece between 2010 and 2014 on the performance of Greek airports. In their study, they analyzed data from 38 airports for the years 2010-2014 using data envelopment analysis and the Malmquist productivity index. They selected runway length, apron area, and passenger terminal area as input variables, while the total number of flights, total passenger numbers, and cargo volume were selected as output variables. The study found that seven airports (Thessaloniki, Heraklio, Kos, Chios, Paros, Kastelorizo, and Kasos) had high efficiency in all periods studied. They also determined that the average efficiency rate of Greek airports was close to 54% and reached 55.6% in 2014.

Yazgan & Karkacier (2015) used the data envelopment technique to measure the efficiency of 37 airports in Turkey. They used annual data for the years 2008, 2009, 2010, and 2011. In their analysis, they determined the number of personnel, operating expenses, terminal area, runway number, and apron number as input variables, while the output variables were passenger numbers, operating revenue, flight traffic, and freight traffic. As a result of their study, they determined that Istanbul Atatürk, Antalya, Muğla Milas Bodrum, Adana, and Tekirdağ Çorlu airports were efficient in all four periods. They also determined that Muğla Dalaman airports were efficient in 2008, Kayseri and Sabiha Gökçen airports in 2009, and Diyarbakır and Sabiha Gökçen airports in 2010 and 2011.

Tsui et al. (2014) measured the operational efficiency of the 21 largest airports in the Asia-Pacific region using the data envelopment method and regression analysis. The input variables in the study were the number of personnel, the number of runways, the total runway length, and the terminal area, while the output variables were the number of passengers, the amount of cargo, and the number of flights. The analysis utilized data from 2002 to 2011. Their study determined that a total of six airports, namely Adelaide, Beijing, Brisbane, Hong Kong, Melbourne, and Shenzhen, were efficient.

Ömürbek, Demirgubuz, & Tunca (2013) measured the efficiency of 40 airports within the State Airports Authority (DHMI) using the data envelopment method. In their study, they used data from four years, from 2007 to 2010, and categorized airports into large, medium, and small-sized airports based on passenger and flight numbers. Flight traffic, commercial flight traffic, cargo traffic, passenger traffic, and sales revenues were the input variables, while output variables included expenses, serviced area, passenger capacity, parking capacity, vehicle parking, apron capacity, aircraft capacity, number of IT devices, number of rescue devices, and number of personnel. The study found that Atatürk and Antalya Airports, which are large-scale airports, Samsun Çarşamba, Kayseri, Van Ferit Melen, and Malatya Airports, and Balıkesir Körfez, Adıyaman, Sinop, and Amasya Merzifon Airports were efficient in terms of domestic, international, total, and flight and passenger traffic. Muğla Airport, a large-scale airport, was the only airport that was inefficient overall.

This study differs from the literature by measuring airport performance to identify the negative effects of the earthquake. The research examines airport performance in the pre- and post-earthquake periods, presenting a new contribution to the literature. The February 6 earthquake affected many areas and sectors in our country, including aviation and, consequently, airports. This impact is particularly evident in airports located in earthquake-prone areas. It is crucial for airport management to identify performance changes at these airports, both before and after the earthquake. This will allow them to determine the extent of the earthquake's impact.

3. Research Method and Data

The aim of this study is to determine the impact of the February 6 earthquake, centered in Kahramanmaraş, referred to as the "Disaster of the Century," on the performance of airports located in the disaster area, considering the pre- and post-disaster periods. In this study, a total of nine airports in the earthquake zone were included in the analysis: Hatay, Kahramanmaraş, Adana, Gaziantep, Adıyaman, Malatya, Elazığ, Şanlıurfa, and Diyarbakır airports.

In the analysis section of this study, data envelopment analysis and Malmquist total factor productivity indices were used to measure airport performance. The analysis was conducted using the output-oriented BCC (variable returns to scale) model. Data envelopment analysis was used to analyze airport efficiency, and Malmquist total factor productivity indices were used to analyze airport efficiency. Relevant methods and information will be examined under the following subheadings.

In today's environment, measuring and improving performance is particularly important for businesses providing services. Because by measuring a business's performance, it can determine what type of strategy it should implement. Data Envelopment Analysis, used to determine the performance of businesses, is an analysis method that can yield successful results in measuring the performance of cohesive units that can produce similar outputs using similar input data (Ulutaş, 2006, p. 2).

Inspired by Farrell's 1957 research, Data Envelopment Analysis was used in 1978 by Charnes, Cooper, and Rhodes in their published work, now known as the CCR model. In recent years, Data Envelopment Analysis has rapidly developed both theoretically and technically. Using CCR in the sense of "constant returns to scale," it attempts to measure the performance of only public sector enterprises. In 1984, Banker, Charnes, and Cooper began measuring performance using the "variable returns to scale" model, now known as the BCC model. Therefore, data envelopment analysis has become capable of investigating types of inefficiency, as well as measuring inefficient resources (Ulutaş, 2006, p. 7).

While the CCR model calculates total efficiency coefficients, the BCC model calculates technical efficiency coefficients. If a technically efficient decision-making unit has scale inefficiency, it cannot be effective in total efficiency results (Peker & Baki, 2009, p. 80).

Efficiency analysis is a crucial management tool for determining the extent to which inputs are being utilized to achieve targeted outcomes. As discussed from time to time in the fields of efficiency measurement and performance measurement techniques, data envelopment analysis is an analysis technique that offers various methods for achieving successful results when ratio analysis and parameterized techniques fail (Erden, 2007, p. 59). In data envelopment analysis, unlike other analysis techniques, the number of inputs and outputs can be multiple. In parametric analysis methods, the number of independent variables is multiple, while the number of dependent variables is only one. Ratio analysis examines the one-dimensional relationship between two different variables. Data envelopment analysis, which can be used for many types of research, allows efficiency measurement with multiple inputs and outputs (Kale, 2009, p. 62). Data envelopment analysis calculates the efficiency of decision-making units operating in the same market compared to different decision-making units. The key point here is that all decision-making units must be located above or below the efficiency threshold. Based on this, the efficient decision-making unit receives a value of "1," while the inefficient decision-making unit receives a value less than 1 (Seyrek and Ata, 2010, p. 70). Another point to consider when applying the model is that for the Data Envelopment Analysis method to yield more robust results, inputs and outputs must be as numerous as possible. Therefore, if accurate results are to be obtained, the study should use as many inputs and outputs as possible. However, the specified input and output variables must be used for all decision-making units included in the study. Furthermore, if the number of inputs is n and the number of outputs is k, having at least n+k+1 decision-making units is an important criterion for the study to yield more accurate results (Bayramoğlu & Toksoy, 2017, p. 84).

The Malmquist total factor productivity index is a method used to identify productivity differences between two different businesses or to examine productivity differences between periods within a single business by considering two different periods. With Malmquist total factor analysis, differences identified in outputs such as technical efficiency, technological efficiency, pure efficiency, scale efficiency, and total factor productivity for the included period can be investigated holistically (Balcı, 2020, p. 38). Technical efficiency changes and technological changes in Malmquist total factor analysis provide information about production constraints. A value greater than 1 in the technical efficiency index indicates the ability to reach the limiting point in production capacity, while a value greater than 1 indicates that the limiting point in production is shifting upward. The technical efficiency index is further divided into two distinct components: pure efficiency and scale efficiency. Scale efficiency changes indicate the firm's ability to produce at a reasonable level. The scale that includes all of these factors and displays the change in total efficiency compared to the previous period is "Total Factor Efficiency Change" (Deliktaş, 2002, p. 263).

In this study measuring airport performance, variable data for nine airports located in the earthquake zone were obtained from the annual activity and statistical reports of the State Airports Authority (DHMI). Information about the airports included in the study and the relevant variables is provided in the tables below.

Table 1.

Airports included in the study

No	Airport	No	Airport
1	Hatay Havalimanı	**6**	Malatya Havalimanı
2	Kahramanmaraş Havalimanı	**7**	Elâzığ Havalimanı
3	Adana Havalimanı	**8**	Şanlıurfa Havalimanı
4	Gaziantep Havalimanı	**9**	Diyarbakır Havalimanı
5	Adıyaman Havalimanı		

Table 2.

Input and output variables used in the study and their explanations

Input	Description
1. Number Of Personnel	Number Of Personnel Working at Airports (Persons)
2. Airport Expenses	Total Expenses Spent by The Airport During the Year (Thousand Tl)
3. Terminal Area	Area Covered by The Airport Terminal (M^2)
Output	**Description**
1. Passenger Count	Total Number of Passengers Departing from The Airport (Persons)
2. Total Number of Flights	Aircraft Traffic Arriving at The Airport (Number of Landings)
3. Freight Traffic	Total Load of Cargo, Mail, and Baggage (Tons)

As shown in Table 2, the study's input variables are personnel, airport expenses, and terminal area, while the output variables are passenger numbers, total number of flights, and freight traffic. Data from the 2021, 2022, and 2023 periods were included in the analysis.

4. Findings of The Study

This section of the study presents the results of data envelopment analysis, including efficiency scores based on variable returns to scale, sensitivity analysis scores, and reference values and clusters. The final section presents the efficiency results from the Malmquist total factor productivity analysis.

4.1. Variable Returns to Scale (BCC) Analysis Results

We can categorize efficiency results into two groups: the airport with the best performance is considered efficient, and the airport with a lower performance is considered inefficient. Output-focused sensitivity analysis determines how much an inefficient airport needs to increase its output to become efficient. The reference results are used to determine the extent to which an inefficient airport will reference an efficient airport. Efficiency scores are presented in Table 3.

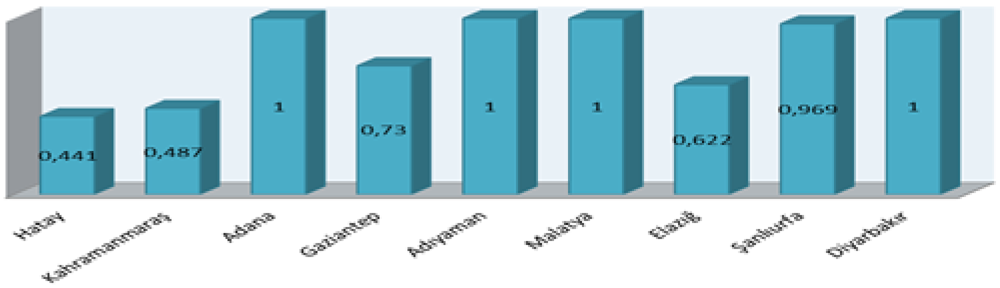
Table 3.

BCC model efficiency scores

	Efficiency Scores (BCC)		
Airport	***2021***	***2022***	***2023***
Hatay	1.000	1.000	0.441
Kahramanmaraş	0.332	0.306	0.487
Adana	1.000	1.000	1.000
Gaziantep	0.789	0.812	0.730
Adıyaman	1.000	1.000	1.000
Malatya	1.000	1.000	1.000
Elâzığ	0.621	0.635	0.622
Şanlıurfa	1.000	1.000	0.969
Diyarbakır	1.000	1.000	1.000
Number of Effective Airports	**6**	**6**	**4**

An examination of Table 3 shows that a total of six airports, namely Hatay, Adana, Adıyaman, Malatya, Şanlıurfa, and Diyarbakır, were active in 2021 and 2022. In 2023, the earthquake year, four airports, namely Adana, Adıyaman, Malatya, and Diyarbakır, were found to be active. This indicates that Hatay and Şanlıurfa airports, which were active before the earthquake, became inactive during the earthquake period. Chart 4 below shows the airport activity scores for 2023, the earthquake year.

Chart 4.
Airport activity scores during the earthquake period



4.2. Sensitivity Analysis Results for Airports

Sensitivity analysis is a type of analysis that provides insights into what inefficient airports need to do to become more efficient. Because the analysis was conducted based on the assumption of variable returns to scale, the sensitivity analysis was calculated based on BCC values. Table 4 shows the sensitivity analysis results for 2021, 2022, and 2023.

Table 4.

Sensitivity analysis scores

Output Variables	*Number Of Passengers*			*Total Number of Flights*			*Freight Traffic*		
Airports	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**
Hatay	-	-	595992	-	-	-	-	-	-
Kahramanmaraş	258007	263608	456968	-	-	-	3106	3255	3255
Adana	-	-	-	-	-	-	-	-	-
Gaziantep	-	-	-	1904	6296	6296	1402	769	769
Adıyaman	-	-	-	-	-	-	-	-	-
Malatya	-	-	-	-	-	-	-	-	-
Elazığ	77113	15668	6946	-	117	117	471	-	-
Şanlıurfa	-	-	107386	-	-	-	-	-	-
Diyarbakır	-	-	-	-	-	-	-	-	-

The sensitivity analysis examines inefficient airports. For example, for Kahramanmaraş Airport to become effective in 2021, it must increase its passenger count by at least 258,007 and its cargo load by at least 3,106 tons. For Gaziantep Airport to become effective, it must increase its total number of flights by 1,904 and its cargo load by 1,402. According to the 2022 sensitivity analysis results, Kahramanmaraş Airport can become effective if it increases its passenger count by 263,608 and its cargo load by 3,255 tons. Gaziantep Airport, on the other hand, must increase its total number of flights by 6,296 and its cargo weight by 769 tons to become effective. Finally, Elazığ Airport must increase its passenger count by 15,668 and its number of flights by 117.

The sensitivity analysis for 2023, an earthquake year, differs from other years in that the sensitivity values increase due to the higher number of inactive airports. According to the table, to achieve active status, Hatay must increase passenger numbers by 595,992, Kahramanmaraş by 456,968, Elâzığ by 6,946, and Şanlıurfa by 107,386. Gaziantep and Elâzığ must increase total flight numbers by 1,303 and 1,154, respectively, and freight traffic by 5,351, Kahramanmaraş by 4,106, Gaziantep by 103, and Şanlıurfa by 1,460.

4.3. Airport References and Reference Values

An inactive decision-making unit's reference to an active decision-making unit helps that decision-making unit become more effective by applying the methods and strategies it has implemented. The decision-making unit uses the active decision-making unit as a model based on the calculated weighting. Inactive decision-making units can use one or more active decision-making units as reference points, while inactive decision-making units can use one or more active units as reference points. Table 5 below shows the references, reference values, and reference counts of airports.

Table 5.

Airport Reference Set

Airports	2021			2022			2023		
	Reference	*Reference Value*	*Reference*	*Reference*	*Reference Value*	*Reference Number*	*Reference*	*Reference Value*	*Reference Number*
Hatay	Hatay	1.000	2	Hatay	1.000	2	Adıyaman Malatya Adana	0.717 0.147 0.136	0
Kahramanmaraş	Malatya Hatay Adana	0.694 0.287 0.019	0	Malatya Hatay Adana	0.696 0.285 0.019	0	Malatya Adana	0.941 0.059	0
Adana	Adana	1.000	3	Adana	1.000	3	Adana	1.000	5
Gaziantep	Diyarbakır Adana	0.509 0.491	0	Diyarbakır Hatay Adana	0.360 0.077 0,563	0	Diyarbakır Adana	0.420 0.580	0
Adıyaman	Adıyaman	1.000	0	Adıyaman	1.000	0	Adıyaman	1.000	2
Malatya	Malatya	1.000	2	Malatya	1.000	2	Malatya	1.000	4
Elazığ	Malatya Hatay Adana	0.734 0.161 0.105	0	Malatya Adana	0.868 0.132	0	Malatya Adana	0.811 0.189	0
Şanlıurfa	Şanlıurfa	1.000	0	Şanlıurfa	1.000	0	Malatya Adıyaman Adana	0.765 0.166 0.069	0
Diyarbakır	Diyarbakır	1.000	1	Diyarbakır	1.000	1	Diyarbakır	1.000	1

Table 5 shows the reference results for 2021. Active airports refer to themselves, while inactive airports refer to active ones. For example, Hatay Airport is active with a value of "1," so its reference is itself. However, Kahramanmaraş Airport can become active only if it references Malatya 0.694%, Hatay 0.287%, and Adana Airport 0.019%. Furthermore, the number of references indicates how many other airports, other than itself, the airport is referenced. For example, in this table, Adana Airport is the most referenced airport, serving as a reference to three other airports.

Ana Airport is again ranked first in terms of reference status based on analysis conducted using 2022 data. Reference results for 2023 are shown. In the earthquake year, the number of reference airports increased compared to previous years due to the number of inactive airports.

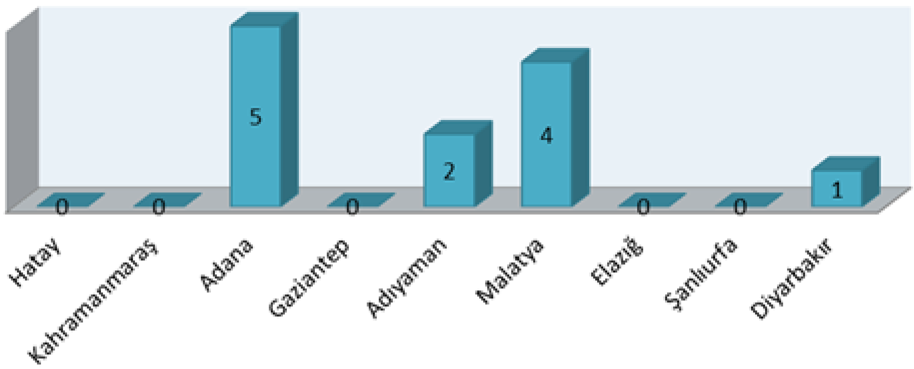
Hatay Airport, which was inactive in 2023, received references from Adıyaman (0.717), Malatya (0.147), and Adana (0.136). Kahramanmaraş and Elazığ Airports received references only from Malatya (0.941) and Adana (0.059). Gaziantep's reference airports were Diyarbakır (0.420) and Adana (0.580), while Şanlıurfa's reference airports were Malatya (0.765), Adıyaman (0.166), and Adana (0.069).

Chart 5 below shows the number of reference airports for 2023, the earthquake year.

Adana Airport, which served as a reference for five airports, was the most referenced airport during this period, as in previous periods.

Chart 5.

Number of references during the earthquake period



4.4. Malmquist Total Factor Productivity Analysis Results

The efficiency analysis evaluates each airport's performance compared to the previous period. Because the analysis is based on the previous year, efficiency measurements were only made for 2022 and 2023. To determine the changes in efficiency values for the nine airports included in the study, an efficiency analysis was conducted using the Malmquist Total Factor Productivity method. Table 6 presents the efficiency analysis results for 2022 and 2023.

Table 6.

Productivity results for 2022 and 2023

Airports	Technical Efficiency Change		Technological Efficiency Change		Pure Activity Change		Scale Efficiency Change		Total Factor Productivity Change	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Hatay	0.952	0.368	0.877	0.917	0.441	1.000	0.835	0.952	0.323	0.873
Kahramanmaraş	0.856	1.676	0.798	0.811	1.592	0.920	1.053	0.931	1.338	0.695
Adana	1.000	1.000	0.880	0.741	1.000	1.000	1.000	1.000	0.880	0.741
Gaziantep	1.027	0.899	0.990	0.937	0.899	1.029	1.000	0.998	0.890	0.962
Adıyaman	1.158	2.072	0.922	0.938	1.000	1.000	2.072	1.158	1.910	1.086
Malatya	1.099	0.780	0.930	0.698	1.000	1.000	0.780	1.099	0.725	0.767
Elazığ	1.180	0.922	0.930	0.722	0.980	1.023	0.940	1.154	0.857	0.852
Şanlıurfa	0.921	0.995	1.036	0.979	0.960	1.000	1.027	0.921	1.031	0.901
Diyarbakır	1.035	0.952	1.210	1.074	1.000	1.000	0.952	1.035	1.152	1.112
Average value	**1.020**	**0.973**	**0.946**	**0.860**	**0.945**	**0.996**	**1.030**	**1.024**	**0.921**	**0.877**

In Table 6, values less than 1 indicate a loss in efficiency; values equal to 1 indicate no change in efficiency; and values greater than 1 indicate an increase in efficiency compared to the previous period. Focusing on the total factor productivity section of this table, which displays 2022 efficiency figures, it is observed that Adıyaman and Diyarbakır airports increased their efficiency, while the other seven airports decreased their efficiency. Furthermore, the highest performance value during this period belonged to Diyarbakır Airport (1.112), while the lowest was for Kahramanmaraş Airport (0.695).

Chart 6 below shows airport efficiency results for 2023, the earthquake year.

Chart 6.

Productivity Results during the Earthquake Period

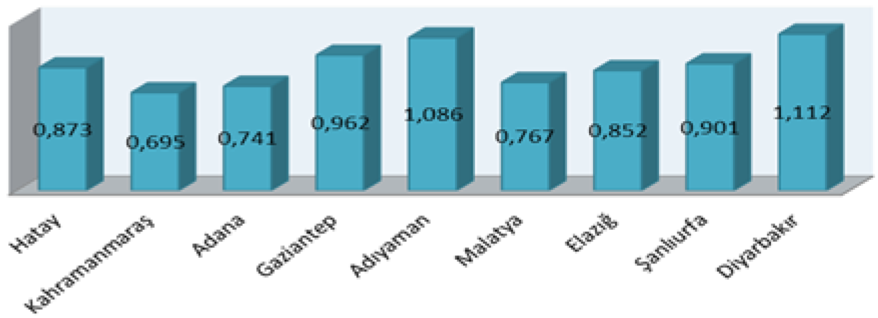


Chart 6 presents the results of the Malmquist total factor productivity analysis for 2023. One of the most striking results is the significant decrease in efficiency at Hatay Airport. The closure of Hatay Airport to air traffic due to extensive damage to its runway and apron following the earthquake was the primary reason for this situation. Unlike Hatay, Kahramanmaraş, Adıyaman, Şanlıurfa, and Diyarbakır airports have increased their efficiency. Humanitarian rescue, aid, and evacuation flights, as well as flights to transport essential supplies to the earthquake zone, have increased the density at these airports, resulting in a positive change in the number of passengers, flights, and cargo. A comparison of performance reveals that Adıyaman Airport has the highest performance value (1.910), while Hatay Airport has the lowest (0.323).

Conclusion and Recommendations

This study examines the impacts of the two major earthquakes centered in Kahramanmaraş on February 6, 2023, which deeply shook our country, on the performance of the airports in Hatay, Kahramanmaraş, Adana, Gaziantep, Adıyaman, Malatya, Elâzığ, Şanlıurfa, and Diyarbakır, located in the earthquake zone. In this study, efficiency measurements for nine airports located in the earthquake zone and operated by DHMI were conducted using the data envelopment method, and efficiency measurements were conducted using Malmquist total factor efficiency analysis.

This study, which adopts an output-oriented approach, found that the number of efficient airports was six in the first two years of the study using BCC efficiency analysis, which stands for variable returns to scale, but this number dropped to four in 2023, the earthquake year. It was observed that Hatay and Şanlıurfa airports lost their efficiency during the earthquake year. When looking at the reference results obtained from the BCC efficiency analysis, it was determined that Adana Airport held the title of "most referenced airport" in all of 2021, 2022, and 2023.

Analyzing the total factor efficiency analyses, it was observed that only two airports, Adıyaman and Diyarbakır airports, were efficient in 2022, and this number increased to four in 2023. These were Adıyaman, Diyarbakır, Kahramanmaraş, and Şanlıurfa airports.

It was also determined that the average efficiency increased in 2023 compared to 2022. It was determined that Hatay Airport's efficiency performance decreased further after the earthquake. It was determined that Kahramanmaraş and Şanlıurfa airports were not efficient in 2023, but they increased their efficiency. This situation arose particularly because some airports were unavailable during the earthquake and flights were diverted from these regions due to the earthquake. Therefore, compared to the same period of the previous year, there was an increase in flight, passenger, and cargo traffic, but due to their lower performance compared to active airports, they were not considered active.

As a result, when evaluated based on variable returns-to-scale efficiency analyses, it was determined that the February 6th earthquake centered in Kahramanmaraş negatively impacted Hatay and Şanlıurfa airports. A Malmquist total factor efficiency analysis determined that Hatay Airport significantly reduced its efficiency. Therefore, based on the results of both analyses, Hatay Airport was found to be the airport most affected by the earthquake. Furthermore, it was determined that the number of efficient airports increased during the earthquake period, and this increase was due to evacuation and relief flights, not normal civilian flight traffic. The prompt completion of the runway repairs at Hatay Airport, which was inactive and significantly reduced in efficiency during the earthquake, is crucial for ensuring full capacity utilization of the airport. It is anticipated that Hatay Airport will once again become an efficient and productive airport as a result of the repairs to the runway and apron and the increase in the number of flights, passengers, and cargo. Therefore, it is recommended that the work be completed expeditiously, the number of domestic flights increased, and the airport be restored to its previous state by adding international flights.

Kahramanmaraş Airport, which was not effective and had a very low efficiency score in any of the 2021, 2022, and 2023 periods included in the analysis, is recommended to increase flight, passenger, and cargo performance. It is recommended that the runway surface irregularities be corrected, the runway, which is currently 2,300 meters, be extended to accommodate wide-body passenger and cargo aircraft, international flights be initiated based on demand, and the number of domestic destinations and flights be increased. Annual data for 2024 was not yet published at the time of the study and therefore could not be included in the study. Future studies should also include data from 2024 to better illustrate the post-earthquake period. Further studies are recommended to conduct analyses using different variables and criteria to assess the impact of the earthquake.

This study specifically reveals which airport experienced the greatest decline in passenger and cargo transport during the earthquake. It also reveals which airport contributed more to the regional transportation process during the earthquake. In this respect, the study makes a significant contribution to the literature.

Compliance with Ethical Standards / Etik Standartlara Uyum

Conflict of Interest (Çıkar Çatışması):

[**TR**] Yazar ve diğer üçüncü kişi ve kurumlarla çıkar çatışmasının olmadığını veya varsa bu çıkar çatışmasının nasıl oluştuğuna ve çözüleceğine ilişkin beyanlar ile yazar katkısı beyan formları makale süreç dosyalarına ıslak imzalı olarak eklenmiştir.

[**EN**] The author(s) declare that they do not have a conflict of interest with themselves and/or other third parties and institutions, or if so, how this conflict of interest arose and will be resolved, and author contribution declaration forms are added to the article process files with wet signatures.

Ethics Committee Approval (Etik Kurul İzni):

[**TR**] Bu makale için etik kurul iznine gerek yoktur. Buna ilişkin ıslak onam formu, makale süreci dosyalarına eklenmiştir.

[**EN**] Ethics committee approval is not required for this article. The corresponding wet consent form has been added to the article process files.

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