Original Paper

European Journal of Digital Economy Research
2021 Vol.2 Issue.2 pp.53-60

INVESTIGATION OF THE IMPACT OF THE PANDEMIC ON EUROPEAN AIRPORTS WITH DATA ENVELOPMENT ANALYSIS

Murat Kemal KELEŞ[*], Temel Caner USTAÖMER[**], Aşkın ÖZDAĞOĞLU[***]

* Assist. Prof. Dr., Isparta University of Applied Sciences, Keçiborlu Vocational School, Department of Transportation Services, Isparta-Turkey, muratkeles@isparta.edu.tr, https://orcid.org/0000-0003-0374-6839.

** Research Assistant Dr., Istanbul Medeniyet University, Department of Aviation Management, Istanbul-Turkey, temelcanerustaomer@anadolu.edu.tr, https://orcid.org/0000-0003-2783-5983.

*** Assoc. Prof. Dr., Dokuz Eylül University, Faculty of Economics and Administrative Sciences, Department of Business, İzmir-Turkey, askin.ozdagoglu@deu.edu.tr, https://orcid.org/0000-0001-5299-0622.

ABSTRACT

Air transport industry is growing rapidly in all around the world. It is especially important that busy airports operate effectively and efficiently. Therefore, measuring airports' efficiency and performance is essential for planning, expansion, and improving the services provided. The Covid-19 pandemic has also negatively affected the air transport industry, especially airports. The aim of this study is to investigate the efficiency of airports in Europe before and after the pandemic using Data Envelopment Analysis (DEA). Therefore, a comparison of the efficiency of airports for the period before and after the pandemic was made using aviation data for the period between 2019 and 2021. In this context, "number of runways", "parking capacity", "distance of the airport to the city center" and "number of aircraft stands" were used as input, and "number of passengers" was used as output. Results reveal that the efficiency values of all airports have decreased significantly compared to values before the pandemic.

Keywords: *International Airports, Pandemic, Efficiency, Data Envelopment Analysis, Linear Programming.*

1. INTRODUCTION

Airports are considered to be strategic assets that help the economic development of a country, as governments worldwide consider them to have an important effect on a country's economic development (Tsui et al., 2014). It is essential to know the effectiveness levels of airports, which are businesses of air transport industry, because airports use scarce public resources, and it is important to use them in the best way.

Air transport contributed to $991 billion and 13.5 million jobs in European economic activity in 2018. An estimated of 2.7 million was directly employed in the aviation industry in Europe in 2018 (ATAG, 2020). Since 2006, European air traffic passenger has increased, except for 2009 and 2020 due to the coronavirus pandemic. In 2020, the pandemic hit European commercial airlines very hard. They reported 34.5 billion U.S. dollars in net profit losses (Mazareanu, 2021). Before the pandemic, the airport industry was forecasted to generate close to $188 billion in 2020. The effect of the pandemic on airport revenues was dramatic, decreasing close to 125 billion USD from airport revenues in 2020, a decrease of 66.3%. The most effected regions were Europe and the Middle East. Airports in Europe lost approximately 4 billion in revenue for 2020 (ACI, 2021).

In this paper, we calculate the efficiency of European airports before and after the pandemic. To calculate the efficiency, the proper inputs and output were determined, and the related data obtained and analyzed. The aims of this study are as follows:

1. To determine inputs and output for evaluation of efficiency in European airports considering the available data and literature review.

2. To use DEA for the evaluation of European airports.

3. To compare the efficiencies of European airports before and after the pandemic.

This paper is structured as follows. Section 2 provides a review of extant literature on the data envelopment analysis used for efficiency evaluation of airports. Section 3 describes methodology. Section 4 presents an application case which measures efficiency of European airports before and after the pandemic. Section 5, the last chapter of the paper, offers concluding remarks about the study.

2. LITERATURE REVIEW

Many studies measured efficiency of companies operating in many industries. This section gives a review of these studies. Costa et al. (2021) employed DEA to evaluate the efficiency of Public Service Obligation (PSO) routes in the European Union and compared them with the efficiency of airlines. Ghimire et al. (2021) developed a stochastic DEA model to assess the efficiency of Ontario universities considering two inputs (expenditures and number of academic staff) and four outputs (tri-council grants, student's satisfaction level, enrolment and number of publications). Pereira et al. (2021) designed DEA model to determine the efficiency of the Portuguese hospitals. Similarly, Onder et al. (2021) employed DEA to evaluate the financial efficiency of U.S. hospitals. Aziz and Chowdhury (2021) evaluated the efficiency of 21 solar mini-grids in Bangladesh, employing a two stage DEA approach. Soltani et al. (2021) employed DEA to evaluate the water quality of dams in Algeria. Peixoto et al. (2020) measured the efficiency of Brazilian hospitals, through the use of Principal Component Analysis, the multivariate statistical technique, and the use of DEA.

Table 1 provides a review of the past studies measuring the productivity and efficiency of airports, namely on those where DEA was used. The table also specifies the selected inputs and outputs.

Table 1. Past Studies

Author	Sample	Inputs	Outputs
Güner and Cebeci (2021)	New Istanbul airport	Airport area Terminal area Length of runways	Passenger numbers Tons of cargo
Zarraga, et al. (2021)	47 Spanish airports	Labour costs Operating costs Depreciation of airside assets Runway surface	Passenger numbers Aircraft movements Cargo Commercial revenues On time performance
Fernandez et al. (2021)	21 largest airports	Number of boarding gates International freight area	Passenger numbers Amount of Cargo Number of workers
Huynh et al. (2020)	Southeast Asian airports	Terminal area Runway length	Air Cargo movement Passenger movement Aircraft movement
Fragoudaki and Giokas (2020)	38 Greek airports	Runway length Terminal size Labour costs	Total passenger numbers, Total aircraft movements, Operating revenues
Abbott (2015)	14 airports in New Zealand	Operating expense Runway length	Aircraft movements per staff employed, Passengers/ runway length, Passenger numbers per staff employed, Aircraft movement/ runway length
Tsui et al. (2014)	11 airports in New Zealand	Number of runways Operating expenses	Aircraft traffic movements Operating revenues Air passenger movements

3. DATA ENVELOPMENT ANALYSIS (DEA)

DEA is used for efficiency evaluation for the decision making units via linear programming (LP). DEA process is as follows (Khalili-Damghani et al., 2015: 765; Huguenin, 2015: 2572).

$$j: decision\ making\ unit, j = 1,2,3,\dots,J$$
$$i: input\ factor, i = 1,2,3,\dots,I$$
$$r: output\ factor, r = 1,2,3,\dots,R$$
$$k: decision\ making\ unit, k = 1,2,3,\dots,K$$
$$I: total\ number\ of\ inputs$$
$$R: total\ number\ of\ outputs$$
$$J: total\ number\ of\ decision\ making\ units$$
$$K: total\ number\ of\ decision\ making\ units$$
$$e_j: efficiency\ value\ of\ decision\ making\ unit\ j$$
$$x_{ik}: value\ of\ decision\ making\ unit\ k\ with\ respect\ to\ input\ factor\ i$$
$$y_{rk}: value\ of\ decision\ making\ unit\ k\ with\ respect\ to\ output\ factor\ r$$
$$\lambda_k: weight\ value\ of\ decision\ making\ unit\ k$$

Objective function of LP for DEA is in Equation 1.

$$z_{\min(j)} = e_j \qquad (1)$$

Output constraints are in Equation 2.

$$\sum_{k=1}^{K} \lambda_k y_{rk} \geq y_{rj}, \forall\, r = 1,2,3,\dots,R \qquad (2)$$

Input constraints are in Equation 3.

$$\sum_{k=1}^{K} \lambda_k x_{ik} \geq e_j x_{ij}, \forall\, i = 1,2,3,\dots,I \qquad (3)$$

Nonnegativity contraints for weight values are in Equation 4.

$$\lambda_k \geq 0,\ \forall\, k = 1,2,3,\dots,K \qquad (4)$$

Nonnegativity contraints for efficiency values are in Equation 5.

$$e_j \geq 0 \qquad (5)$$

Next section shows the application.

4. APPLICATION

The purpose of this study is to find out the impact of the pandemic on the efficiency of the top 15 airports in Europe. In order to determine the effect of the pandemic on the efficiency of airports, data were obtained one year before the pandemic and one year after the pandemic. The top 15 European airports in terms of 2020 passenger traffic were included in the study (Port Authority NY NJ, 2021). The inputs and outputs were selected out of the most widely used inputs and outputs in the literature. Table 2 shows the inputs and outputs.

Table 2. Input & Output Factors

Input (I)	Description
1. Parking capacity	Number of parking spaces at the airport (units)
2. Number of runways	Number of runways at the airport (units)
3. Distance of the airport to the city center	Distance of the airport to the city center (km)
4. Number of aircraft stands	Number of aircraft stands (units)
Output (O)	**Description**
1. Number of passengers	Number of domestic and international passengers

The top 15 European airports considering passenger traffic are included in the study. The ranking of the airports was obtained from 2020 Airport Traffic Report written by Port Authority NY NJ. The top 15 European airports are given in Table 3.

Table 3. Top 15 European Airports

DMU	Airports
DMU1	Istanbul Airport
DMU2	Charles de Gaulle Airport
DMU3	Heathrow Airport
DMU4	Amsterdam Airport Schipol

DMU5	Sheremetyevo International Airport
DMU6	Frankfurt am Main Airport
DMU7	Adolfo Suarez Madrid-Barajas Airport
DMU8	Domodedovo International Airport
DMU9	Josep Tarradellas Barcelona-EI Prat Airport
DMU10	Vnukovo International Airport
DMU11	Munich Airport
DMU12	Pulkovo Airport
DMU13	Orly Airport
DMU14	Gatwick Airport
DMU15	Leonardo da Vinci-Fiumicino Airport

Pre-Covid values of European airports are in Table 4, Post-Covid values of international airports are in Table 4. Inputs and output data were collected form websites of airports and aviation authorities of mentioned airports.

Table 4. Pre-Covid Data

	O1	I1	I2	I3	I4
DMU1	61716477	40000	5	54	371
DMU2	76309503	9185	4	23	317
DMU3	81018291	64000	2	23	133
DMU4	71563336	20000	6	18	225
DMU5	49933000	4100	3	29	118
DMU6	70347983	15000	4	12	142
DMU7	61734037	17000	4	13	175
DMU8	28300000	9600	3	42	143
DMU9	52686314	12500	3	15	123
DMU10	24001521	550	2	28	60
DMU11	47900000	12000	2	29	135
DMU12	19581262	2863	2	23	47
DMU13	31825561	1090	3	13	104
DMU14	46600000	40000	1	48	119
DMU15	40000000	12000	4	32	130

Source: Amsterdam Sciphol Airport (2021); Barcelona Airport (2021); Fraport (2021); Gatwick Airport (2021); General Directorate of State Airports Authority (2021); Groupe ADP (2021); Heathrow Airport (2021); Munich Airport (2021); Sheremetyova Airport (2021); AENA (2021); Domodedovo Airport (2021); Vnukovo Airport (2021); Pulkovo Airport (2021); AVIA (2021); Fiumicino Airport (2021).

Table 5. Post-Covid Data

	O1	I1	I2	I3	I4
DMU1	16693233	40000	5	54	371
DMU2	12063826	9185	4	23	317
DMU3	9142926	64000	2	23	133
DMU4	10650823	20000	6	18	225
DMU5	19784000	4100	3	29	118
DMU6	10143456	15000	4	12	142
DMU7	17112389	17000	4	13	175
DMU8	16300000	9600	3	42	143
DMU9	12739259	12500	3	15	123
DMU10	12565241	550	2	28	60
DMU11	11100000	12000	2	29	135
DMU12	10944000	2863	2	23	47
DMU13	6896957	1090	3	13	104
DMU14	10200000	40000	1	48	119
DMU15	10000000	12000	4	32	130

Source: Amsterdam Sciphol Airport (2021); Barcelona Airport (2021); Fraport (2021); Gatwick Airport (2021); General Directorate of State Airports Authority (2021); Groupe ADP (2021); Heathrow Airport (2021); Munich Airport (2021); Sheremetyova Airport (2021); AENA (2021); Domodedovo Airport (2021); Vnukovo Airport (2021); Pulkovo Airport (2021); AVIA (2021); Fiumicino Airport (2021).

LP model of DMU1 for Pre-Covid data is as follows.

Objective function is as follows.

$$z_{\min(1)} = e_1$$

The constraint for the first input is as follows.

$$\begin{aligned} 40000\lambda_1 + 9185\lambda_2 + 64000\lambda_3 + 20000\lambda_4 \\ + 4100\lambda_5 + 15000\lambda_6 + 17000\lambda_7 \\ + 9600\lambda_8 + 12500\lambda_9 + 550\lambda_{10} \\ + 12000\lambda_{11} + 2863\lambda_{12} \\ + 1090\lambda_{13} + 40000\lambda_{14} \\ + 12000\lambda_{15} - 40000e_1 \leq 0 \end{aligned}$$

The constraint for the second input is as follows.

$$\begin{aligned} 5\lambda_1 + 4\lambda_2 + 2\lambda_3 + 6\lambda_4 + 3\lambda_5 + 4\lambda_6 + 4\lambda_7 + 3\lambda_8 \\ + 3\lambda_9 + 2\lambda_{10} + 2\lambda_{11} + 2\lambda_{12} \\ + 3\lambda_{13} + 1\lambda_{14} + 4\lambda_{15} - 5e_1 \leq 0 \end{aligned}$$

The constraint for the third input is as follows.

$$\begin{aligned} 54\lambda_1 + 23\lambda_2 + 23\lambda_3 + 18\lambda_4 + 29\lambda_5 + 12\lambda_6 \\ + 13\lambda_7 + 42\lambda_8 + 15\lambda_9 + 28\lambda_{10} \\ + 29\lambda_{11} + 23\lambda_{12} + 13\lambda_{13} \\ + 48\lambda_{14} + 32\lambda_{15} - 54e_1 \leq 0 \end{aligned}$$

The constraint for the last input is as follows.

$$371\lambda_1 + 317\lambda_2 + 133\lambda_3 + 225\lambda_4 + 118\lambda_5 + 142\lambda_6 + 175\lambda_7 + 143\lambda_8 + 123\lambda_9 + 60\lambda_{10} + 135\lambda_{11} + 47\lambda_{12} + 104\lambda_{13} + 119\lambda_{14} + 130\lambda_{15} - 371e_1 \leq 0$$

The constraint for the output is as follows.

$$61716477\lambda_1 + 76309503\lambda_2 + 81018291\lambda_3 + 71563336\lambda_4 + 49933000\lambda_5 + 70347983\lambda_6 + 61734037\lambda_7 + 28300000\lambda_8 + 52686314\lambda_9 + 24001521\lambda_{10} + 47900000\lambda_{11} + 19581262\lambda_{12} + 31825561\lambda_{13} + 46600000\lambda_{14} + 40000000\lambda_{15} \geq 61716477$$

Nonnegativity constraint for the weights of DMU's is as follows.

$$\lambda_k \geq 0,\ \forall\, k = 1,2,3,\ldots,13$$

Nonnegativity constraint for the efficiency value of the airport is as follows.

$$e_1 \geq 0$$

Efficiency values of the airports can be seen in Table 6.

Table 6. Pre and Post-Covid Efficiency Values of Airports (Different DEA Models)

	Pre-Covid Efficiency	Post-Covid Efficiency
DMU1	0.509	0.498
DMU2	1.000	0.638
DMU3	1.000	0.676
DMU4	0.729	0.489
DMU5	1.000	1.000
DMU6	1.000	0.701
DMU7	0.854	1.000
DMU8	0.494	0.803
DMU9	0.939	0.884
DMU10	1.000	1.000
DMU11	1.000	0.790
DMU12	0.923	1.000
DMU13	1.000	0.928
DMU14	1.000	1.000
DMU15	0.638	0.459

Examining Table 6 reveals that the efficiency values of some airports have increased after the pandemic. In the next phase of the study, Pre-covid and Post-Covid data are integrated in the same DEA model. The results of the integrated DEA model can be seen in Table 7.

Table 7. Pre and Post-Covid Efficiency Values of Airports (Integrated DEA Model)

	Pre-Covid Efficiency	Post-Covid Efficiency
DMU1	0.509	0.138
DMU2	1.000	0.158
DMU3	1.000	0.113
DMU4	0.729	0.108
DMU5	1.000	0.396
DMU6	1.000	0.144
DMU7	0.854	0.237
DMU8	0.494	0.284
DMU9	0.939	0.227
DMU10	1.000	0.524
DMU11	1.000	0.232
DMU12	0.923	0.516
DMU13	1.000	0.217
DMU14	1.000	0.219
DMU15	0.638	0.160

The value of 1 means efficient and a value of less than 1 means inefficient. According to the result of the analysis, the impact of the pandemic on the efficiency of airports is dramatic. Table 7 shows that Chares de Gaulle, Heathrow, Sheremetyevo, Frankfurt, Barcelona, Vnukovo, Munich, Pulkovo, Orly, and Gatwick airports were efficient before the pandemic. The airports with the lowest efficient values before the pandemic were Domodedovo Airport with a score of 0.494, Istanbul Airport with a score of 0.509, and Leonardo da Vinci Airport with a score of 0.638.

Examining the efficiency values of the post-pandemic period, it is seen that the airports that were efficient before the pandemic (Chares de Gaulle, Heathrow, Sheremetyevo, Frankfurt, Barcelona, Vnukovo, Munich, Pulkovo, Orly and Gatwick) are inefficient. It is noteworthy that Heathrow Airport is the airport whose efficiency has decreased the most from 1 to 0.113. Heathrow airport was in the second place after Dubai International Airport in the world based on international passenger traffic in 2019 (ACI, 2020). The cessation of international flights due to the pandemic has had a negative effect on the number of passengers of the airport in particular. Examining Table 7 reveals that airports with the lowest efficiency value in the post-pandemic period are Amsterdam with a score of 0,108, Heathrow with a score of 0.113, Istanbul with a score of 0,138, Frankfurt with a score of 0,144, and Charles de Gaulle with a score of 0.158, respectively.

5. CONCLUSION

There has been a rapid growth in the air transport sector in the world compared to other sectors. It is especially important that busy airports operate effectively and efficiently. Aviation sector is the worst affected by Covid-19 pandemic. Due to the pandemic, the bans imposed by countries and restrictions imposed have had a negative impact on passenger and freight transportation, making airports inactive. The airports that have suffered the most from this are undoubtedly the ones serving international passengers.

In the study examining efficiency of airports in Europe in pre-and post-pandemic period, 4 inputs and 1 output were used. The inputs are; “number of runways”, “parking capacity”, “distance of the airport to the city center”, and “number of aircraft stands”. The output is “number of passengers”. The following results were obtained by data envelopment analysis.

Considering the pre-pandemic period in terms of efficiency, Chares de Gaulle, Heathrow, Sheremetyevo, Frankfurt, Barcelona, Vnukovo, Munich, Pulkovo, Orly and Gatwick Airport were efficient. The last three airports with the lowest efficiency values are Domodedovo, Istanbul and Leonardo da Vinci airports, respectively.

When the post-pandemic period is evaluated in terms of efficiency, there is a dramatic change compared to the pre-pandemic period. During this period, none of the airports are efficient. It has been determined that Heathrow Airport is the airport with the lowest efficiency value compared to the period before the pandemic. The fact that the pandemic has affected international flights the most explains the significant reduction in efficiency. The airports with the lowest efficiency value in the post-pandemic period are Amsterdam, Heathrow, Istanbul, Frankfurt, and Charles de Gaulle, respectively. In future studies, efficiency analyses of different airports in the world can be evaluated. The inputs and outputs used in the evaluation can be changed.

REFERENCES

1. ABBOTT, M. (2015), “Reform and Efficiency of New Zealand’s Airports”, Utilities Policy, 36, pp. 1-9.
2. ACI (2021), The Impact of Covid-19 on the Airport Business and the Path to Recovery, https://aci.aero/2021/03/25/the-impact-of-covid-19-on-the-airport-business-and-the-path-to-recovery/, (Accessed on 25.10.2021).
3. ACI (2020), ACI Reveals Top 20 Airports for Passenger Traffic, Cargo, and Aircraft Movements, https://aci.aero/2020/05/19/aci-reveals-top-20-airports-for-passenger-traffic-cargo-and-aircraft-movements/, (Accessed on 25.10.2021).
4. AENA (2021), Relevant Figures, https://portal.aena.es/en/corporate/relevant-figures.html, (Accessed on 24.10.2021).
5. Amsterdam Sciphol Airport (2021), Traffic and Transport Figures, https://www.schiphol.nl/en/schiphol-group/page/transport-and-traffic-statistics/, (Accessed on 24.10.2021).
6. ATAG (2020), Aviation Benefits Beyond Border, https://aviationbenefits.org/media/167186/abbb2020_full.pdf, (Accessed on 24.10.2021).
7. AVIA (2021), Passenger Traffic at Russian Airports, https://www.avia-adv.ru/en/placement/airports/passenger-traffic.htm, (Accessed on 24.10.2021).
8. AZIZ, S., and CHOWDHURY, S. (2021), “Performance Evaluation of Solar Mini-Grids in Bangladesh: A Two-Stage Data Envelopment Analysis”, Cleaner Environmental Systems, 2, pp. 1-12.
9. Barcelona Airport (2021), Facts and Figures, https://barcelonaairport.com/statistics/, (Accessed on 24.10.2021).
10. COSTA, J., ALVES, T., ANDRADE, A., and KALAKOU, S. (2021), “Assessing Efficiency in Public Service Obligations in European Air Transport Using Data Envelopment Analysis”, Case

Studies on Transport Policy, https://doi.org/10.1016/j.cstp.2021.09.004.
11. Domodedovo Airport (2021), News, https://www.dme.ru/en/, (Accessed on 24.10.2021).
12. FERNANDEZ, X., GUNDELFINGER, J., and MILLAN, P. (2021), "The Impact of Logistics and Intermodality on Airport Efficiency", Transport Policy, https://doi.org/10.1016/j.tranpol.2021.05.008.
13. Fiumicino Airport (2021), Passenger Numbers, https://www.fiumicinoairport.net/passenger-statistics.shtml, (Accessed on 24.10.2021).
14. FRAGOUDAKI, A. and GIOKAS, D. (2020), "Airport Efficiency in the Dawn of Privatization: The Case of Greece", Journal of Air Transport Management, 86, pp. 1-14.
15. Fraport (2021), Traffic Figures, https://www.fraport.com/en/investors/traffic-figures.html, (Accessed on 24.10.2021).
16. Gatwick Airport (2021), Key Facts, https://www.gatwickairport.com/business-community/about-gatwick/company-information/gatwick-key-facts/, (Accessed on 24.10.2021).
17. General Directorate of State Airports Authority (2021), Statistics, https://www.dhmi.gov.tr/Sayfalar/EN/Statistics.aspx, (Accessed on 24.10.2021).
18. GHIMIRE, S., AMIN, S., and WARDLEY, L. (2021), "Developing New Data Envelopment Analysis Models to Evaluate the Efficiency in Ontario Universities", Journal of Informetrics, 15, pp. 1-17.
19. Groupe ADP (2021), Traffic of Paris Aeroport and Groupe ADP Airports, https://www.parisaeroport.fr/en/group/finance/investor-relations/traffic, (Accessed on 24.10.2021).
20. GÜNER, S., and CEBECI, H. (2021), "Output Targeting and Capacity Utilization for A New-Built Airport: Analysis for the New Airport in Istanbul", Socio- Economic Planning Sciences, 76, pp. 1-9.
21. Heathrow Airport (2021), Facts and Figures, https://www.heathrow.com/company/about-heathrow/facts-and-figures, (Accessed on 24.10.2021).
22. HUGUENIN, Jean-Marc. (2015), "Data Envelopment Analysis and Non-Discretionary Inputs: How to Select the Most Suitable Model Using Multi-Criteria Decision Analysis", Expert Systems with Applications, 42, 2570–2581.
23. HUYNH, T., KIM, G., and HA, H. (2020), "Comparative Analysis of Efficiency for Major Southeast Asia Airports: A Two-Stage Approach", Journal of Air Transport Management, 89, pp. 1-9.
24. KHALILI-DAMGHANI, Kaveh, TAVANA, Madji, and HAJİ-SAAMİ, Elham. (2015), "A Data Envelopment Analysis Model with Interval Data and Undesirable Output for Combined Cycle Power Plant Performance Assessment", Expert Systems with Applications, 42, 760–773.
25. MAZAREANU, E. (2021), "Air Transportation Industry in Europe- Statistics & Facts", https://www.statista.com/topics/6657/air-transportation-industry-in-europe/#dossierKeyfigures.
26. MLYNARSKI, W., PREDKI, A., and KALISEWSKI, A. (2021), "Efficiency and Factors Influencing it in Forest Districts in Southern Poland: Application of Data Envelopment Analysis", Forest Policy and Economics, 130, pp. 1-11.
27. Munich Airport (2021), Traffic Figures, https://www.munich-airport.com/traffic-figures-263342, (Accessed on 24.10.2021).
28. ONDER, O., COOK, W., and KRISTAL, M. (2021), "Does Quality Help the Financial Viability of Hospitals? A Data Envelopment Analysis Approach", Socio-Economic Planning Sciences, https://doi.org/10.1016/j.seps.2021.101105.
29. PEIXOTO, M., MUSETTI, M., and MENDONÇA, M. (2020), "Performance Management in Hospital Organizations from the Perspective of Principal Component Analysis and Data Envelopment Analysis: The Case of Federal University Hospitals in Brazil", Computers & Industrial Engineering, 150, pp. 1-13.
30. PEREIRA, M., FERREIRA, D., FIGUEIRA, J., and MARQUES, R. (2021), "Measuring the Efficiency of the Portuguese Public Hospitals: A Value Modelled Network Data Envelopment Analysis with Simulation", Expert Systems With Applications, 181, pp. 1-14.
31. Port Authority NY NJ (2021), 2020 Airport Traffic Report, https://www.panynj.gov/airports/en/statistics-general-info.html, (Accessed on 24.10.2021).
32. Sheremetyevo Airport (2021), Sheremetyevo Today, https://www.svo.aero/en/about/sheremetyevo-today, (Accessed on 24.10.2021).
33. SOLTANI, A., OUKIL, A., BOUTAGHANE, H., BERMAD, A., and BOULASSEL, M. (2021), "A New Methodology for Assessing Water Quality, Based on Data Envelopment Analysis: Application to Algerian Dams", Ecological Indicators, 121, pp. 1-18.

34. TSUI, K., GILBEY, A., and BALLI, O. (2014), "Estimating Airport Efficiency of New Zealand Airports", Journal of Air Transport Management, 35, pp. 78-86.

35. Vnukovo Airport (2021), News, http://www.vnukovo.ru/en/press/news/vnukovo-airport-increased-passenger-traffic-by-7-8-in-december-2019/, (Accessed on 24.10.2021).

36. ZARRAGA, A., PORTILLO, F., and MOLINERO, C. (2021), "The Impact of the Economic Crisis on the Efficiency of Spanish Airports: A DEA Visualisation Analysis", Research in Transportation Business & Management, https://doi.org/10.1016/j.rtbm.2021.100689.