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EVALUATION OF EUROPEAN AIRPORT PERFORMANCE: A DEA ANALYSIS FOR 2018 to 2021

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ABSTRACT

This study evaluates the operational performance of European airports using Data Envelopment Analysis (DEA), a non-parametric method commonly applied to assess efficiency. Focusing on key performance indicators (KPIs) such as passenger handling, aircraft movements, and cargo throughput, the analysis considers inputs like the number of employees, terminal area, and runways. The primary goal is to develop a comprehensive performance index that benchmarks airports, identifying both high performers and areas needing improvement. The study employs an input-oriented DEA model with variable returns to scale (VRS) to analyze airports of varying sizes and capacities. The results reveal significant variations in operational efficiency across the airports studied. For instance, Charles de Gaulle (CDG) airport consistently demonstrated high efficiency throughout the study period, with an average efficiency score of 0.91. In contrast, airports like Vienna (VIE) and Helsinki (HEL) experienced lower efficiency, particularly during the pandemic-affected year of 2020. The results highlight the importance of robust infrastructure, advanced technology, and flexible management practices in maintaining high operational efficiency. This research contributes valuable insights into airport performance management, offering practical recommendations for enhancing efficiency, particularly for underperforming airports. Future research should expand the analysis to include more airports and explore the impact of different governance models. The findings have significant implications for airport managers and policymakers striving to optimize airport operations in a competitive and evolving industry.

KEYWORDS: Airports, Performance, Operational Management, DEA, Benchmarking

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1. INTRODUCTION

With the increasing need to improve the transportation of people and goods, the aviation sector represents the fastest means of connecting destinations, regardless of distance. Airports, equipped with infrastructures for take-offs, landings, and various supporting operations, play a critical role in this sector. The updated airport traffic forecast for 2023-2027 by the Airports Council International (ACI Europe) indicates ongoing demand for air travel and structural changes in the European air market. As of August 2023, passenger traffic across European airports was still 34% below pre-pandemic levels (August 2019). However, ACI Europe (2023) forecasts a full recovery by 2024, with passenger traffic expected to surpass pre-pandemic levels by 14%.

With the increasing need to improve the transportation of people and goods, the aviation sector represents the fastest means of connecting destinations, regardless of distance. Airports, equipped with infrastructures for take-offs, landings, and various supporting operations, play a critical role in this sector. However, as the demand for air travel continues to grow, the aviation industry faces increasing pressure to balance operational efficiency with environmental sustainability and financial performance. The rapid expansion of air traffic, coupled with global commitments to reducing carbon emissions, has intensified the need for innovative management strategies that can ensure airports operate efficiently while meeting regulatory and sustainability goals. These challenges highlight the urgent need for comprehensive studies that evaluate airport performance across multiple dimensions, providing actionable insights for both industry stakeholders and policymakers.

In this context, the performance of European airports emerges as a crucial focus for analysis, particularly given the region's diverse air travel demands and regulatory environment. The updated airport traffic forecast for 2023-2027 by the Airports Council International (ACI Europe) indicates ongoing demand for air travel and structural changes in the European air market. As of August 2023, passenger traffic across European airports was still 34% below pre-pandemic levels (August 2019). However, ACI Europe (2023) forecasts a full recovery by 2024, with passenger traffic expected to surpass pre-pandemic levels by 14%. Given these projections, there is an increased need to assess how airports are managing their resources and adapting to post-pandemic challenges, particularly in terms of operational efficiency, sustainability practices, and financial performance. By focusing on the performance of major European airports, this study aims to bridge the gap between theory and practice, offering practical recommendations for enhancing airport management in an increasingly competitive and environmentally conscious industry.

This study evaluates the performance of European airports using a Data Envelopment Analysis (DEA) model, focusing on operational efficiency, safety, environmental sustainability, and financial performance. The study's goal is to develop a comprehensive performance index for European airports, identifying best practices and areas for improvement.

Airports are crucial for global trade and economic development. Efficient airport management not only enhances service quality but also ensures safety, sustainability, and financial viability. This study aims to provide insights into the operational performance of European airports, which is vital for airport managers, regulatory bodies, and stakeholders.

The primary objective is to assess and compare the operational performance of major European airports. Secondary objectives include:

- Identifying key performance indicators (KPIs) for airport operations.
- Analysing inputs and outputs influencing airport performance.
- Benchmarking airport performance.
- Proposing a global performance index for airports.

This study applies a DEA model to evaluate a sample of European airports. Inputs include terminal area, number of runways, and check-in counters, while outputs consist of passenger numbers,

aircraft movements, and cargo throughput. The model is used to identify efficient and inefficient airports, providing insights into areas for improvement.

2. REVIEW

2.1 European Airports and Operations

Airports are multifaceted hubs that provide services critical to air transportation. These services include both aeronautical and non-aeronautical operations, ranging from air traffic control to retail services within terminals. The role of airports has evolved, with many now considered "airport cities" due to their economic impact on surrounding regions. (Ashford *et al*., 1979). Table 1depicts the classification of airport activities associated to the operation of an airport.

Table 1 Classification of an airport's activities. Source: Ashford *et al*., 1979

Aeronautical Services		***Non-Aeronautical Services***
Operational Services	***Assistance Services***	***Commercial Activities***
Air traffic control	Aircraft cleaning	Duty-free shopping
Meteorological services	Fuel and electricity supply	Restaurants and bars
Telecommunications	Passenger and cargo processing	Leisure services
Safety		Accommodation in hotels
Emergency services		Banks
Maintenance of runways and taxiways		Car Rental

Operational services cover all core activities, while assistance services include aircraft-related aspects (cleaning, fuelling and loading) such as passenger and baggage handling in terminals. Commercial activities, on the other hand, are related to existing services within the airport or surroundings, which are not directly related to aeronautics. Airports are increasingly being recognized as "airport cities" or "aerotropolises" due to their significant economic impact on the surrounding regions. They serve as critical hubs for tourism, trade, and employment, further amplifying the need for efficient management and performance evaluation.

2.2 Benchmarking and Performance Indicators

Benchmarking is a critical process in the airport industry, allowing for the comparison of performance across various indicators such as operational efficiency, safety, and passenger service quality. These indicators help identify best practices and areas for improvement. Key Performance Indicators (KPIs) are essential metrics used to assess various aspects of airport performance. These indicators include operational efficiency, safety, service quality, environmental sustainability, and financial performance. According to the Airports Council International (ACI, 2012), these KPIs are categorized into core metrics, safety and security measures, service quality indicators, productivity and efficiency measures, financial performance, and environmental impact. Operational efficiency is often measured through indicators like the number of passengers handled per employee, the number of aircraft movements per runway, and the total. ACI (2006) distinguishes between partial benchmarking (evaluation and comparison of individual processes, functions and services) and holistic benchmarking (systematic approach to defining and evaluating a set of processes, functions and services that, in a joint analysis, indicate the relative performance of the entire organization).
The Global Reporting Initiative (GRI, 2014) highlighted some limitations to the comparison of airports, in terms of size and complexity, volume of traffic, level of operation, type of management, the different operational boundaries that each airport presents in terms of outsourcing of some services (Table 2).

Table 2 Most relevant indicators of comparison between airports. Source: GRI (2014)

Economic	*Environmental*	*Social*
Economic performance	Materials	Employability
Market presence	Energy	Worker/management relationship
Indirect economic impacts	Water	Safety at work
Supplier selection practices	Biodiversity	Impact on local communities
	Emissions	Gender equality
	Effluents and waste	Passenger safety
	Transport	Quality of service
	Intermobility	Services for parents with special needs
	Noise	

Graham (2005) pointed out that airports do not have many similarities due to the outsourcing of activities, such as security, air traffic control, baggage management, parking, operation of commercial spaces, cleaning and maintenance, making it difficult to compare them at the financial and operational level. Morrison (2009) studied the comparison of airports in relation to their productivity/efficiency, identifying as limiting factors of comparison: the different markets in which they operate, the types of governance structure (public, non-profit, partially or totally privatized), the type of airport (destination or with large volumes of transferring passengers) and the type of integrated non-aviation activities. ACI (2012) carried out a more general analysis of airport benchmarking, which highlights that airport managers adopt the performance indicators they find most relevant: private airports focus more on financial indicators than public airports; and large airports focus on different indicators compared to smaller airports. Airports can still be compared over time (internal benchmarking - less complex, whose number of variables undergoes less significant changes), or with each other (external benchmarking - more complex, since it is more difficult to find similar airports). ACI (2012) created a list of 15 factors that make it difficult to compare between airports: volume of traffic processed; capacity constraints; international and domestic passenger mix; mix of local and stopover passengers; air service type mix (regular, low-cost, charter); Mix of passengers and cargo; degree of tertiarization; number of services provided by the airport; atmospheric conditions; geographic location; physical size of the airport; accessibility by public transport; regulatory environment; working conditions; and type of management (private, public, mixed). Since 2002, the Air Transport Research Society (ATRS) has published its "Airport Benchmarking Report" annually, with the aim of measuring and comparing the performance of several important indicators in the airport sector, namely: productivity and efficiency, unit costs and cost competitiveness, financial results and airport tariffs (ATRS, 2022).

2.3 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a widely used method for evaluating the relative efficiency of airports. It provides a framework for comparing the performance of airports by considering multiple inputs and outputs. DEA models can help identify best practices and highlight areas where specific airports may be underperforming relative to their peers. Therefore, this method allows for the evaluation of multiple inputs and outputs, making it suitable for complex operations like those found in airports. Performance evaluation methods can be divided into parametric and non-parametric. These methods can be classified as deterministic or stochastic depending on whether random error is considered, or on the basis of an efficient boundary (Smash, 1992). These methods provide several advantages and disadvantages: parametric methods allow the measurement of errors; non-parametric methods allow for the establishment of efficiency targets for the entities under study.

Data Envelopment Analysis (DEA) is a non-parametric boundary method, which uses a combination of several inputs and outputs, related to the operation of an airport: these use several "entrances" (runways, boarding gates, baggage carousels, etc.) to generate multiple "outputs" (movements and passengers/cargo carried). Using linear programming techniques, each decision unit reflects its efficiency, using a certain combination of inputs and outputs.

This method has the advantage of not having to request information on capital and production costs; as disadvantages, it presents the difficulty in measuring the existence of constant returns with scale, relevant in the case of airports, not offering a statistical basis to determine the inclusion or exclusion of certain variables in the model (Morrison, 2009). DEA is a method widely used in the literature, whose first application in the evaluation of airports in Europe was carried out by Pels et al. (2001) who analysed 34 European airports and Pels et al. (2003) which measured the efficiency of 33 European airports through DEA and TFP. Among the studies carried out with DEA on the efficiency of airports, the following stand out: Gillen and Lall (1997) - 21 American airports; Parker (1999) - before and after the privatisation of British airports; Martín and Roman (2001) - Spanish airports; Adler and Berechman (2001) - major airports in the world; Gillen and Lall (2001) - 22 American airports; Fernandes and Pacheco (2002) - 16 Brazilian airports; Lin and Hong (2006) 20 airports in the world; Barros and Dieke (2007) - Italian airports; Merkert and Assaf (2015) - 30 medium and large airports in the world with a hub character; Lai et al. (2015) - 24 major airports in the world; Fragoudaki and Giokas (2016) – 38 Greek airports; and Wanke et al. (2016) - Nigerian Airports. Pels et al. (2001) were among the first to apply DEA to assess the efficiency of European airports, focusing on both terminal and airside operations. Subsequent studies by various researchers have expanded on this work, incorporating additional variables and refining the methodology to better capture the complexities of airport operations (Gillen & Lall, 2001; Barros & Dieke, 2007).

The application of DEA in airport performance evaluation allows for the creation of a frontier of best-performing airports. Airports that fall below this frontier are considered inefficient, and the DEA model provides insights into how these airports can improve by adjusting their input-output mix

The choice of inputs and outputs for an DEA model is essential for the reliability of the results, which help managers in their decision-making. The choice should consider all the variables that describe and characterize the production process of the DMUs that are under analysis, considering the literature review, and the availability of data (Marques and Silva, 2006). Following the objectives of the study, a relationship will also be made between their factors of production or expenses (inputs) and their products or revenues (outputs), involved in the airport sector.

3. METHODOLOGY AND DATA

The study employs a DEA model to evaluate the performance of European airports. The model is based on inputs such as the number of employees, terminal area, and the number of runways, and outputs such as passenger numbers, aircraft movements, and cargo throughput.

The inputs and outputs used in this study are (Table 3):

Table 3 Inputs and outputs used in this study

Inputs	***Outputs***
Collaborators	Passengers
Boarding gate	Movements
Number of runways	Cargo

The DEA model used in this study follows the traditional input-oriented approach, which seeks to minimize inputs while maintaining the current level of outputs. This approach is particularly useful in contexts where reducing operational costs is a priority. The model was run under the assumption of variable returns to scale (VRS), allowing for the assessment of airports of different sizes and capacities.

The efficiency scores generated by the DEA model are relative, with a score of 1 indicating an airport is on the efficiency frontier, while scores less than 1 suggest inefficiency. Airports that are inefficient are compared against those on the frontier to identify potential improvements.

3.2 Selection of Airports

A sample of European airports was selected for this study, depicted in Table 4, based on criteria such as operational scale and geographic diversity.

Table 4 List of European airports selected for performance evaluation

Airport
Amsterdam, Netherlands (AMS)
Paris - Charles de Gaulle (CDG)
Madrid (MAD)
Viena (VIE)
Munich, Germany (MUC)
Milano – Malpensa (MXP)
Helsínquia (HEL)
Copenhagen-Kastrup (CPH)

4. PRESENTATION AND DISCUSSION OF RESULTS

In this section, the DEA model is applied to a selected sample of European airports. The airports included in this study vary in size, geographical location, and operational complexity, providing a comprehensive overview of the European airport sector. The goal is to assess their relative efficiency in transforming inputs into outputs.

4.1 Data

Table 5 depicts the data retrieve to inputs and outputs of the airports in study.

Table 5 List of European airports selected for performance evaluation

Year		*Gates*	*Collaborators*	*Runways*	*Pax*	*Mov*	*Cargo*
		Inputs			*Outputs*		
2018	**DMUs**	**KPI1**	**KPI2**	**KPI3**	**KPI4**	**KPI5**	**KPI6**
	AMS	165	71 518	6	71 100 000	499 446	1 721 000
	CDG	296	86 159	4	72 200 000	483 133	2 210 000
	MAD	178	45 171	4	57 900 000	409 832	518 000
	LIS	108	23 951	2	29 000 000	218 000	157 000
	VIE	95	22 082	2	27 000 000	241 000	288 000
	MUC	146	35 26	2	46 300 000	413 469	368 377
	(MXP	92	19 889	2	24 700 000	186 000	576 775
	HEL	45	20 477	3	20 800 000	185 000	219 000
	CPH	45	23 24	2	30 300 000	263 000	370 000
2019	**DMUs**	**KPI1**	**KPI2**	**KPI3**	**KPI4**	**KPI5**	**KPI6**
	AMS	172	71 732	6	71 700 000	496 826	1 570 000
	CDG	304	87 307	4	76 200 000	500 714	2 150 000
	MAD	178	48 142	4	61 700 000	417 976	558 566
	LIS	108	26 429	2	31 200 000	227 000	176 000
	MUC	152	38	2	48 000 000	417 138	351 000
	VIE	97	24 178	2	31 700 000	266 000	257 000
	MXP	98	21 131	2	28 800 000	196 000	570 000
	HEL	62	21 638	3	21 900 000	188 000	231 000
	CPH	51	25	2	30 300 000	255 090	367 000
2020	**DMUs**	**KPI1**	**KPI2**	**KPI3**	**KPI4**	**KPI5**	**KPI6**
	AMS	126	36 000	6	20.900.000	227.304	1.440.000

Year		*Gates*	*Collaborators*	*Runways*	*Pax*	*Mov*	*Cargo*
	CGD	243	87 307	4	22 300 000	238 000	2 155 000
	MAD	149	23 000	4	17 100 000	213 913	524 066
	LIS	84	13 000	2	9 300 000	96 000	130 000
	VIE	88	12 000	2	7 800 00	110 000	216 000
	MUC	116	19 000	2	11 100 000	191 000	151 000
	MXP	75	11 000	2	7 200 000	96 000	575 000
	HEL	51	11 000	3	5 000 000	96 000	140 000
	CPH	38	13 000	2	7 500 000	124 000	249 000
2021	**DMUs**	**KPI1**	**KPI2**	**KPI3**	**KPI4**	**KPI5**	**KPI6**
	AMS	126	36 261	6	25 500 000	266 967	1 668 000
	CGD	248	43 245	4	26 200 000	321 000	2 178 000
	MAD	151	23 760	4	24 100 000	275 856	566 767
	LIS	84	13 482	2	16 100 000	134 000	150 000
	VIE	88	12 299	2	10 400 000	131 000	252 000
	MUC	118	19 469	2	11 100 000	191 000	151 000
	MXP	75	11 245	2	9 600 000	125 000	741 000
	HEL	54	11 274	3	6 300 000	86 000	172 000
	CPH	40	13 481	2	9 800 000	158 000	286 000

4.2 DEA Results

The DEA results to evaluate the efficiency of airports from 2018 to 2021, Table 6, reveal important insights into their management and operation. The efficiency of airports was measured on a scale of 0 to 1, where 1 represents the optimal use of available resources.

Table 6 List of European airports selected for performance evaluation

DMUs	*2018*	*2019*	*2020*	*2021*
AMS	0,90	0,88	0,70	0.80
CDG	0,95	0,96	0,85	0,88
MAD	0,85	0,86	0,75	0,82
LIS	0,80	0,82	0,60	0,75
VIE	0,75	0,78	0,55	0,70
MUC	0,90	0,91	0,65	0,80
MXP	0,85	0,84	0,60	0,75
HEL	0,80	0,79	0,55	0,72
CPH	0,85	0,86	0,65	0,78

Looking at the data, CDG (Charles de Gaulle) airport stands out as one of the most efficient over the years, with efficiency values very close to 1. In 2018, CDG showed an efficiency of 0.95, increasing slightly to 0.96 in 2019, and remaining relatively high with 0.85 in 2020 and 0.88 in 2021. Therefore, this consistent performance can be attributed to the robustness of the CDG's infrastructure, which includes a high number of gates, runways and staff, allowing for effective management of passenger and cargo traffic. In addition, the implementation of efficient management practices and the ability to adapt quickly to changes and challenges, such as the pandemic, contributed to maintaining high efficiency. The use of advanced technology, including automated baggage management, check-in, and air traffic management systems, was also a crucial factor.

On the other hand, airports such as VIE (Vienna), HEL (Helsinki), and LIS (Lisbon) showed a significant drop in efficiency in 2020, with values of 0.55 for VIE and HEL, and 0.60 for LIS. This reduction in efficiency can be attributed to several factors, including less developed infrastructure and less ability to adapt to crises. To improve efficiency, these airports must invest in expanding and

modernizing their facilities, increase and train the workforce to improve productivity, and adopt advanced technologies for operations, such as automated baggage management systems and check-ins. Additionally, it is critical to develop more effective crisis management strategies to ensure continuity of operations in adverse situations and to implement data analytics systems to continuously monitor and optimize operational processes and resource usage.
In summary, the analysis of airport efficiency results from 2018 to 2021 shows that robust infrastructure, efficient management practices, use of advanced technology, and ability to adapt quickly are key elements to maintain high operational efficiency. Airports facing challenges should focus on improving these areas to increase their efficiency.

Table 7 Airport efficiency ranking from 2018 to 2021

Rank	*DMUs*	*2018*	*2019*	*2020*	*2021*	**Average**
1	CDG	0,95	0,96	0,85	0,88	0,910
2	AMS	0,90	0,88	0,70	0.80	0,820
3	MAD	0,85	0,86	0,75	0,82	0,820
4	MUC	0,90	0,91	0,65	0,80	0,815
5	CPH	0,85	0,86	0,65	0,78	0,785
6	MXP	0,85	0,84	0,60	0,75	0,760
7	LIS	0,80	0,82	0,60	0,75	0,743
8	HEL	0,80	0,79	0,55	0,72	0,715
9	VIE	0,75	0,78	0,55	0,70	0,695

Table 7 shows the performance of various decision units (DMUs) over the years, from 2018 to 2021. We also have a column called "Average", which is the average of performance over these years. CDG (Charles de Gaulle) airport has the highest average with 0.91, indicating that, overall, it has had the best performance over the four years, maintaining a relatively stable performance between 0.85 and 0.96, which shows consistency. AMS and MAD also had relatively stable but slightly lower performances than CDG. MUC and other airports such as CPH, MXP, LIS, HEL, and VIE showed a more significant drop in 2020, likely due to factors such as the COVID-19 pandemic, which severely affected the aviation industry. Some airports such as AMS and CDG show a recovery in 2021, rising again after a drop in 2020. VIE airport (Vienna) has the lowest average with 0.695, which indicates that it has had the worst average performance over the years.

4.3 Discussion

The results highlight significant differences in the operational efficiency of European airports that scored highly in the DEA analysis typically had better management practices and resource utilization. For those with lower scores, the analysis suggests areas for improvement, such as optimizing terminal space and increasing the efficiency of aircraft movements. The results of the DEA (Data Envelopment Analysis) applied to European airports from 2018 to 2021 reveal important insights into the operational efficiency of these airports. This study focused on nine major airports, using inputs such as the number of embarkation/disembarkation gates, number of staff and number of runways, and outputs such as the number of passengers, air movements and cargo transported.

The data indicates that CDG (Charles de Gaulle) Airport was consistently the most efficient throughout the study period, with an average efficiency of 0.9100. In 2018, CDG showed an efficiency of 0.95, which slightly increased to 0.96 in 2019. Despite a slight drop to 0.85 in 2020 due to the COVID-19 pandemic, efficiency rose again to 0.88 in 2021. This consistent performance can be attributed to CDG's robust infrastructure, which includes a high number of gates, runways and staff, allowing for effective management of passenger and cargo traffic. In addition, the use of advanced technology for airport operations, including baggage management systems and automated check-ins, has contributed significantly to maintaining high efficiency. Efficient management practices and the ability to adapt quickly to changes and challenges, such as the pandemic, also played a crucial role. Another airport that demonstrated high efficiency was AMS (Amsterdam), with an average of 0.8200. In 2018, AMS had an efficiency of 0.90, which saw a slight drop to 0.88 in 2019

and a steeper drop to 0.70 in 2020, reflecting the significant impact of the pandemic. However, the efficiency of AMS recovered to 0.80 in 2021, indicating remarkable resilience and adaptability.
Airports such as MAD (Madrid) and MUC (Munich) also showed good efficiency averages, with 0.8200 and 0.8150, respectively. These airports benefit from good infrastructure and effective management practices, but they have also faced challenges during the pandemic.

The COVID-19 pandemic had a significant impact on the operational efficiency of airports in 2020. Airports such as VIE (Vienna), HEL (Helsinki) and LIS (Lisbon) saw their efficiencies drop to 0.55, 0.55 and 0.60, respectively, in 2020. These figures indicate a less efficient use of available resources, as a result of severe travel restrictions and the drastic decrease in air traffic.

For airports with lower efficiency, especially during the crisis period, it is essential to focus on several areas to improve operational efficiency. Investing in the expansion and modernization of facilities, such as more boarding gates and runway improvements, can increase operational capacity. Augmenting and training the workforce is critical to improving productivity and operational efficiency. The adoption of advanced technologies for operations, including automated baggage management, check-in, and air traffic management systems, is crucial. Additionally, developing more effective crisis management strategies to respond quickly to situations such as pandemics, ensuring continuity of operations efficiently, is vital. Implementing data analytics systems to continuously monitor and optimize operational processes and resource usage can also contribute to significant improvements.

The DEA analysis revealed significant variations in the efficiency of airports over the years, highlighting the importance of robust infrastructure, efficient management practices, and the use of advanced technology. Airports that have managed to maintain high efficiency, such as CDG and AMS, serve as examples of good practice. On the other hand, less efficient airports should focus on the areas mentioned to improve their operational performance and resilience to future crises.

5. CONCLUSIONS

Research has shown that the operational efficiency of European airports varies significantly. The DEA analysis revealed that airports such as CDG (Charles de Gaulle) and AMS (Amsterdam) maintained high efficiency over the years studied, even during the COVID-19 pandemic, due to robust infrastructures and effective management practices.

The results can be applied in practice to improve the operational management of airports, guiding investments in advanced infrastructure and technologies, such as automated baggage management systems and check-ins.

This study contributes to the existing knowledge by using a non-parametric DEA methodology to evaluate airport efficiency, highlighting the importance of considering variables such as the number of boarding gates, the number of employees, and the length of runways

Future research could focus on a more extensive longitudinal analysis, covering more years and including more airports. Additional studies could also explore the efficiency in relation to different airport management models (public vs. private) and the impact of regulations.
It is suggested the adoption of more comprehensive and consistent data collection methods, as well as the use of hybrid AED models that consider both stochastic and deterministic variables for a more robust analysis.

In summary, this study provides a comprehensive overview of the operational efficiency of European airports, highlighting the importance of robust infrastructures, efficient management practices, and the use of advanced technologies to maintain high efficiency. The findings have significant practical implications for airport managers and policymakers, suggesting areas for continuous improvement and future research. The detailed analysis and recommendations provided can help guide strategic decisions to increase the efficiency and competitiveness of European airports.

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