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The Duality of Global Airports: A Study on the Divergence Between Passenger Nodes and Cargo Hubs

A Dualidade dos Aeroportos Globais: Um Estudo sobre a Divergência entre Nós de Passageiros e Centros de Carga

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Abstract

This study analyzes the divergence between the roles of global airports as passenger nodes and cargo hubs. Although airports are crucial components of global transportation networks, leadership in passenger connectivity does not guarantee dominance in cargo operations. The research employs a comparative framework integrating three key data sources: the 2024 Air Connectivity Index (ACI), 2024 Freight & Mail volumes from the Airports Council International (ACI), and the 2023 Logistics

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Performance Index (LPI) Infrastructure sub-index from the World Bank. A Spearman correlation is used to examine the association between connectivity and the quality of national logistics infrastructure across 20 European airport5. The results reveal a notable specialization among airports. European airports such as Frankfurt (FRA) and Paris (CDG) present a balanced performance. The correlation analysis found no statistically significant association between the ACI Connectivity Index and the LPI ranking (ρ = -0.235, p = 0.318), suggesting that high-quality national logistics performance does not directly translate into greater air passenger connectivity. The study concludes that air cargo competitiveness is a multidimensional outcome, significantly influenced by institutional frameworks and specific policies beyond physical infrastructure. It is argued that airports must adopt integrated strategies that combine infrastructure, institutional efficiency, and targeted cargo policies rather than relying solely on connectivity as a measure of success.

Keywords*:* Airport competitiveness, air cargo operations, passenger connectivity, digital transformation, infrastructure quality.

Resumo

Este estudo analisa a divergência entre os papéis dos aeroportos globais como nós de passageiros e centros de carga. Embora os aeroportos sejam componentes cruciais das redes de transporte mundial, a liderança em conectividade de passageiros não garante domínio nas operações de carga. A pesquisa adota um quadro comparativo que integra três fontes principais de dados: o Índice de Conectividade Aérea de 2024 (ACI), os volumes de Carga e Correspondência de 2024 do Airports Council International (ACI) e o subíndice de Infraestrutura do Índice de Desempenho Logístico (LPI) de 2023 do Banco Mundial. Utilizou-se a correlação de Spearman para examinar a associação entre conectividade e qualidade da infraestrutura logística nacional em 20 aeroportos europeus. Os resultados revelam uma especialização notável entre os aeroportos. Aeroportos europeus como Frankfurt (FRA) e Paris (CDG) apresentam um desempenho equilibrado. A análise de correlação não identificou associação estatisticamente significativa entre o ACI Connectivity Index e o ranking do LPI (ρ = -0.235, p = 0.318), sugerindo que um elevado desempenho logístico nacional não se traduz diretamente em maior conectividade aérea de passageiros. O estudo conclui que a competitividade da carga aérea é um resultado multidimensional, fortemente influenciado por estruturas institucionais e políticas específicas, para além da infraestrutura física. Argumenta-se que os aeroportos devem adotar estratégias integradas que combinem infraestrutura, eficiência institucional e políticas direcionadas à carga, em vez de depender exclusivamente da conectividade como medida de sucesso.

Palavras-chave: *Competitividade aeroportuária, operações de carga aérea, conectividade de passageiros, transformação digital, qualidade da infraestrutura*

1. Introduction

Airports are essential components of global transportation networks, supporting both passenger travel and cargo operations. Passenger connectivity facilitates tourism and business travel, while cargo operations contribute to international trade and economic activity (Button & Taylor, 2000). Air cargo is particularly vital for integrating global value chains and supporting regional and national economies (Hong, 2025).

Shishani et al. (2023) emphasizes the importance of evaluating cargo airport competitiveness using multiple criteria, including transport capacity, airport operations and facilities, economic growth, financial performance, and airport brand value. Shishani also notes that during the COVID-19 pandemic, airlines redeployed passenger aircraft for cargo missions, highlighting the need for airports to adapt their operations and policies.

Hong (2025) analyzes air cargo in the Northeast Asian region, noting that while some airports showed weak growth between 2010 and 2023, others such as ICN, PVG, TPE, and HKG maintained positive growth. He identifies three critical factors for agile air cargo hubs: digital transformation, flight services, and location and accessibility. Digital transformation enhances airport agility by integrating the air cargo supply chain, improving operational efficiency, and maintaining competitiveness. The pandemic further emphasized the importance of agility, as passenger aircraft were used to meet increasing e-commerce demands.

Van Asch et al. (2019) discuss airport competitiveness in cargo operations, highlighting infrastructure, connectivity, and the differentiation of services as key determinants of performance.

This paper examines global airports by comparing passenger connectivity, measured by the Air Connectivity Index (ACI, 2024), with cargo operations, measured by air freight and mail volumes (2024), and contextualized using the Logistics Performance Index (LPI) infrastructure subindex (World Bank, 2023). The goal is to identify patterns of specialization among airports, highlighting those that function primarily as passenger nodes, cargo hubs, or both.

2. Literature Review

Recent literature has emphasized the importance of agility in airport management and aviation supply chains. Hong (2025) highlight that digital transformation, flight services, information sharing, and accessibility are key factors enhancing the agility of cargo airports, particularly in hubs such as Incheon International Airport (ICN). These factors allow airports to respond efficiently to disruptions, increase resilience, and strengthen long-term competitive advantage.

Yacoubian & Merdinian (2025) show that robust logistics infrastructure, measured through the Logistics Performance Index (LPI), is positively correlated with countries' export capacity. This demonstrates that investments in physical, institutional, and digital infrastructure not only support operational efficiency at airports but also broader economic performance, integrating global value chains.

Şişman (2025) complements this perspective by analyzing agility in aviation management from a supply chain standpoint. The study emphasizes that agility enables organizations to rapidly adapt to environmental changes, maintain operational continuity during crises such as the COVID-19 pandemic, and optimize resources through collaboration and adoption of digital technologies. Şişman also identifies research gaps in sustainability and stakeholder collaboration, suggesting that agility is not merely an operational efficiency capability but a strategic tool for organizational resilience and competitiveness.

Together, these studies provide a conceptual framework linking infrastructure, digitalization, and operational agility as essential elements for strengthening airport competitiveness and efficiently integrating supply chains in the global context.

3. Methodology

This study examines the relationship between airport infrastructure, connectivity, and cargo operations by integrating data from multiple authoritative sources to provide a comparative analysis of major international airports. A Spearman correlation calculation between the Air Connectivity Index and the LPI Infrastructure ranking positions was included to validate the comparative analysis.

3.1 Data Sources

Three primary datasets are employed:

Logistics Performance Index (LPI) – Infrastructure Subindex (2023)
Provided by the World Bank (2023), this subindex measures the quality of trade and transport-related infrastructure, including ports, railroads, roads, and airports. It serves as a proxy for the underlying logistics capabilities of each country, which can impact airport performance.

Air Connectivity (2024)
Data on airport connectivity are sourced from the Airports Council International (ACI, 2024) Airport Connectivity Report, which evaluates the global network reach of airports in terms of passengers.

Freight & Mail Traffic (Metric Tonnes, 2024)
Cargo traffic data, measured in metric tonnes of freight and mail, are obtained from ACI (2024). This metric reflects the actual throughput of goods handled by each airport and serves as an indicator of operational performance in the air cargo sector.

3.2 Sample and Selection Criteria

The analysis focuses on a selection of leading international airports recognized for their cargo operations. Each airport's national LPI infrastructure score, global connectivity, and freight & mail traffic are compiled for 2024. This combination allows a multi-dimensional comparison across airports, highlighting relative strengths and weaknesses.

This table presents the 2024 Air Connectivity Index (ACI) values for major European airports, alongside their respective national Logistics Performance Index (LPI) Infrastructure scores from 2023. The inclusion of both indicators allows for a comparative view of passenger connectivity performance at the airport level and the broader quality of trade and transport infrastructure at the national level. This integrated perspective facilitates the identification of potential gaps between airport connectivity and the supporting logistics environment. Provided LPI Infrastructure scores belong to the country where that airport is located.

Table 1. Air Connectivity Index (ACI) from 2024 and LPI Infrastructure scores from 2023

Index Value	Airport Code	Country / City	LPI Infrastructure Score 2023	LPI General/Overall Rank 2023
4.866	IST	Turkey – Istanbul	3.4	42
4.580	AMS	Netherlands – Amsterdam	4.2	5
4.579	LHR	United Kingdom – London	3.7	25
4.397	CDG	France – Paris	3.8	13
4.301	FRA	Germany – Frankfurt	4.3	4
3.771	MAD	Spain – Madrid	3.8	15
3.309	MUC	Germany – Munich	4.3	4
3.304	BCN	Spain – Barcelona	3.8	15
3.277	FCO	Italy – Rome	3.7	22
2.799	PMI	Spain – Palma de Mallorca	3.8	15
2.782	LGW	United Kingdom – London	3.7	25
2.766	ATH	Greece – Athens	3.7	21
2.494	VIE	Austria – Vienna	3.9	7
2.451	CPH	Denmark – Copenhagen	4.1	3
2.401	ZRH	Switzerland – Zurich	4.4	6
2.396	DUB	Ireland – Dublin	3.5	28
2.360	SAW	Turkey – Istanbul	3.4	42
2.341	SVO	Russia – Moscow	2.7	95
2.244	LIS	Portugal – Lisbon	3.6	40
2.225	ORY	France – Paris	3.8	13

Sources: Airport Industry Connectivity Report 2024 (ACI Europe); World Bank, *Logistics Performance Index 2023*.

The second table presents LPI Infrastructure 2023 scores, alongside Freight & Mail volumes (metric tonnes, 2024) from Airports Council International, showing actual cargo throughput at each airport.

Table 2. Top 20 busiest airports in terms of Cargo and their LPI Infrastructure index scoring

Airport	2024 Cargo in Metric Tonnes	2023 LPI Infrastructure Score
HONG KONG, HONG KONG (HKG)	4,938,211	4.0
SHANGHAI, CHINA (PVG)	3,778,331	4.0
MEMPHIS, USA (MEM)	3,754,236	3.9
ANCHORAGE, USA (ANC)	3,699,284	3.9
LOUISVILLE, USA (SDF)	3,152,969	3.9
INCHEON, KOREA (ICN)	2,946,902	4.1
MIAMI, USA (MIA)	2,753,450	3.9
DOHA, QATAR (DOH)	2,616,849	3.8
GUANGZHOU, CHINA (CAN)	2,381,901	4.0
TAIPEI, TAIWAN (TPE)	2,270,974	3.8
DUBAI, UAE (DXB)	2,176,843	4.1
LOS ANGELES, USA (LAX)	2,174,455	3.9
CHICAGO, USA (ORD)	2,074,006	3.9
SINGAPORE, SINGAPORE (SIN)	2,008,300	4.6
TOKYO, JAPAN (NRT)	2,004,716	4.2
FRANKFURT, GERMANY (FRA)	1,991,048	4.3
ISTANBUL, TURKEY (IST)	1,984,744	3.4
PARIS, FRANCE (CDG)	1,914,681	3.8
SHENZHEN, CHINA (SZX)	1,881,468	4.0
CINCINNATI, USA (CVG)	1,695,904	3.9

Content source: Airports' Council International (ACI), airport authorities and World Bank.

3.3 Analytical Approach

Since the selected variables are not directly comparable on a common scale, the study adopts a descriptive and comparative framework to examine their relationships. Additionally, a Spearman correlation analysis was later introduced to provide an alternative perspective and strengthen the robustness of the findings.

- Step 1: Airports are ranked independently by LPI infrastructure, connectivity, and freight & mail traffic.
- Step 2: Comparative tables are created to highlight the relative performance of airports across these dimensions.
- Step 3: Observations are drawn on potential relationships between infrastructure quality, connectivity, and cargo throughput, without inferring direct causal links.

- Step 4: Spearman rank correlation between the Air Connectivity Index (ACI) values and the LPI ranks for the 20 major European airports to measure if there is a relation between these 2 variables.

While this study's connectivity and cargo metrics focus on specific airports, the analytical framework intentionally incorporates country-level data, such as the Logistics Performance Index (LPI). The authors acknowledge that although airports are distinct operational entities, they are intrinsically embedded within the broader logistical, regulatory, and economic framework of their respective nations. Therefore, national-level indicators of infrastructure quality and institutional efficiency provide a foundational context for understanding an airport's potential and performance. By contextualizing airport-specific data within these national metrics, this approach allows for a more holistic analysis and serves as a valid basis for constructing and testing broader theories on the determinants of airport competitiveness

This approach allows for a nuanced understanding of how infrastructure and connectivity may support air cargo performance while acknowledging the limitations of direct measurement and cross-metric comparison.

3.4 Limitations

An important limitation of this analysis is the temporal mismatch between the variables considered. While the Air Connectivity Index (ACI) and cargo volumes are taken from 2024 data, the Logistics Performance Index (LPI) values correspond to the 2023 release.

Furthermore, when incorporating the numerical ranking of each country within the LPI, we relied on the overall LPI ranking rather than the infrastructure sub-index specifically. This methodological choice was necessary to ensure consistency across countries but may reduce the precision of the relationship being tested because of the unavailability of the LPI Infrastructure specific ranking.

Nevertheless, the values tend to be consistent between the two: countries with high scores in the infrastructure sub-index generally also exhibit high overall LPI values. Similarly, this correspondence holds for the other sub-indices, so that the relative position of countries in the overall ranking fairly reflects their performance in each specific dimension of international logistics.

To conclude, it must be acknowledged that the Air Connectivity Index for countries outside Europe was not included, as such information was not publicly available at the time of the study. This limitation introduces a regional bias into the analysis, which should be noted when interpreting the findings.

4. Results and Discussion

The list of the top 20 busiest airports in terms of freight (Table 2) shows that hubs such as Hong Kong International (HKG) and Incheon International (ICN) demonstrate outstanding performance in cargo volumes. According to the ACI Asia-Pacific & Middle East Air Connectivity Ranking (2025), Incheon ranked third in Asia for passenger connectivity, while Hong Kong ranked tenth. This indicates that if there were a direct relationship between connectivity and cargo performance, Hong Kong should appear at the top of both rankings. The divergence instead suggests that cargo leadership is driven by differentiated strategies beyond passenger connectivity.

As we explained, in order to further investigate whether there is an association between airport connectivity and the quality of national logistics infrastructure, we calculated a Spearman rank correlation between the Air Connectivity Index (ACI) values and the LPI ranks for the 20 major European airports included in this study. Given that one of the variables (LPI) is an ordinal ranking, Spearman's rho was preferred over Pearson's correlation to present the table number 3 based on the information shown in table number 1.

Table 3. Spearman Rank Correlation between ACI Index Value (2024) and LPI Rank (2023)

Spearman's rho (ρ)	-0.235
p-value	0.318
N (observations)	20

Source: Own elaboration based on data from ACI Europe (*Airport Industry Connectivity Report 2024*) and World Bank (*Logistics Performance Index 2023*).

As shown, there is no evidence of a significant correlation between the ACI Connectivity Index value and the LPI overall ranking, nor with the table comparisons using the Infrastructure subindex. For example, Turkey, ranked 42nd in the overall LPI, appears at the top of Table 1.

Kasarda & Green (2014) establish that air cargo is positively associated with both trade volumes and GDP per capita, although its economic contribution depends heavily on institutional quality. Factors such as air service liberalization, customs efficiency, and low corruption enhance the extent to which air cargo can stimulate foreign investment and overall economic growth.

Factors such as air service liberalization, customs efficiency, and low corruption enhance the degree to which air cargo can stimulate foreign investment and overall economic growth. Applied to the present findings, this suggests that the performance of leading cargo hubs like HKG or ICN cannot be explained by infrastructure alone, but must also consider institutional frameworks that facilitate efficient cargo flows.

These findings highlight that connectivity and cargo performance do not converge into a single hierarchy. In the European sample, hubs such as Frankfurt (FRA) and Paris (CDG) show relatively balanced performance between cargo and passenger connectivity. The United States ranks among the world's most connected air transport nations, supported by its high-volume cargo hubs. According to Airports Council International, six U.S. airports (Atlanta, Dallas Fort Worth, Denver, Chicago O'Hare, Los Angeles and John F. Kennedy) are among the 20 busiest in the world for passenger traffic (ACI, 2025).

Moreover, U.S. airports such as Memphis and Anchorage continue to stand out as global leaders in cargo volumes, reinforcing the country's pivotal role in both passenger and freight connectivity (ACI, 2025).

For instance, Singapore shows the highest LPI infrastructure score of 4.6 but is not the leading airport in cargo volumes. Hong Kong, with a lower score of 4.0, ranks first, showing that logistics infrastructure quality is not linearly related to air cargo performance.

A comparative analysis of the tables revealed no significant relationship between air connectivity and cargo volume, and vice versa, indicating that higher connectivity does not necessarily correspond to greater freight throughput, nor does higher freight volume imply greater connectivity.

Furthermore, Burghouwt (2017) argues that air connectivity outcomes are not purely market-driven, but strongly influenced by public policy through regulation of market access, airport capacity, service quality, and cost structures. In this light, the divergence between passenger and cargo leadership among airports can be seen as the outcome of differentiated policy and investment choices. Airports that seek to strengthen their cargo competitiveness must therefore not only expand physical capacity but also align policy conditions and service frameworks that encourage efficient cargo operations.

In summary, the combined analysis of the three datasets demonstrates that air cargo competitiveness is a multidimensional outcome. While infrastructure quality at the national level matters, institutional frameworks and policy choices strongly condition how airports convert connectivity into cargo performance. These findings provide empirical backing for the argument that airports should not rely solely on passenger connectivity as a proxy for cargo competitiveness, but instead pursue integrated strategies that combine infrastructure, institutional efficiency, and targeted cargo policies.

Conflict of Interest: The authors declare no conflicts of interest.

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