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Maximizing Operational Efficiency in Air Cargo: An In-Depth Comparative Study of Five Leading Combination Carriers

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ABSTRACT

This study evaluates the efficiency of five combination carriers using the DEA Super-Radial model, emphasizing the critical yet often overlooked cargo operations. Many studies predominantly focus on passenger-centric metrics, neglecting the complexities and significance of cargo operations in airline revenue streams. This research addresses this gap by examining both passenger and cargo services, thus providing a holistic understanding of airline operations. The super-efficiency rankings for 2022-23 revealed that no combination carrier achieved efficiency under the Super-CCR-I and Super-CCR-O models. However, Lufthansa and Air China were efficient according to the Super-BCC-I model, while LATAM and Air France KLM were efficient under the Super-BCC-O model. The study identifies inefficiencies in the remaining carriers and suggests improvements such as adapting to a dynamic business environment, investing in fuel-efficient aircraft, optimizing route planning and cargo operations, adopting sustainable practices, and leveraging advanced technologies. By utilizing the DEA Super Radial model, this study offers valuable insights to enhance operational efficiency and profitability, ultimately contributing to a more sustainable aviation industry.

Keywords: Combination carriers, Data envelopment analysis, Super-efficiency, DEA Super-Radial model, Air Cargo

INTRODUCTION

The passenger and cargo sectors of the air transport industry form crucial pillars of the global transportation infrastructure. In the coming two decades, the air cargo volume is anticipated to grow at a rate of 1.5 to 2 times faster than the global GDP. Such a significant growth rate, surpassing that of air passenger traffic, underscores the escalating importance of air freight in the global economy. This trend indicates that air freight is becoming an increasingly vital component of international commerce, facilitating the swift movement of goods across borders, and enhancing global supply chain efficiency. The rising demand for air cargo services is likely to drive innovations in logistics, improvements in cargo handling technology, and investments in more efficient and sustainable aircraft. As a result, the air cargo sector will play a pivotal role in supporting economic growth, enabling businesses to reach new markets, and maintaining the smooth operation of global trade networks (Hong & Zhang, 2010). Air cargo moves an overwhelming number of commodities; its value accounts for an impressive 35–40% of all goods but makes up less than 1% of every commodity moved (Boeing, 2016). This research uses the DEA Super Radial Model to identify the most efficient airlines among five prominent carriers—Lufthansa Airlines, Cathay Pacific Airlines, Air China Airlines, LATAM Airlines, and Air France KLM Airlines.

Data Envelopment Analysis (DEA) using the Super Radial model serves as a powerful analytical tool for evaluating the efficiency of airlines, particularly in terms of resource usage and cost management. By analyzing the input-output relationships, DEA identifies airlines that achieve optimal outputs with given inputs or minimize inputs for a given level of output. This analysis offers valuable insights that can assist airlines in optimizing their input-output management and establishing more effective cost strategies. Importantly, this study addresses a significant gap in the literature by focusing on the intricacies of cargo operations within the aviation industry.

Many studies predominantly concentrate on passenger-centric metrics which often overlook the complexities of the cargo operations although cargo operations that play a significant role in an airline's revenue streams. However, they are often overlooked in academic literature, leading to a lack of understanding of their impact on airline efficiency. By drawing attention to combination carriers—airlines that provide both passenger and cargo services this study fills this gap and provides a more comprehensive understanding of airline operations. Furthermore, the application of the Super Radial technique in DEA allows for the evaluation of the combination carrier's efficiency in managing expenses and resources. This approach enables airlines to better understand their operational performance and identify areas for improvement, particularly in the often-neglected area of cargo operations. Overall, this study's focus on the DEA Super Radial model offers valuable insights that can aid airlines in enhancing their operational efficiency and profitability, ultimately contributing to a more sustainable aviation industry.

REVIEW OF LITERATURE

An airline's efficiency may be defined as its capacity to maximize operations while consuming the fewest resources possible. (Forsyth et al., 1986). More broadly, it is the capacity to carry out tasks efficiently, effectively, and without wasting any resources. As airline efficiency analysis has started to incorporate both operational and social considerations, methods for measuring efficiency have evolved to cope with the increasing complexity of analysis. For aircraft efficiency, researchers are now using techniques like data envelopment analysis (DEA) instead of the traditional regression analysis (Mallikarjun, 2015). To assess decision-making units (DMUs) and their productivity efficiency, DEA uses a variety of inputs and outputs (Sengupta, 1999). When evaluating multiple decision-making units, which frequently have many inputs and outputs, DEA employs a nonparametric technique. Assigning numerical values to input and output variables is not necessary for this analytical approach. Instead, the units of measurement for inputs and outputs can be determined by the study, independent of their true market prices. Models of linear programming would then be used to investigate the relationships between the input and output variables. To begin the study, an optimum DMU must be developed. From there, the relative efficiency of several DMUs is compared to the optimal DMUs and each other. Several industries, notably the aviation industry, have employed DEA to assess operational and corporate performance (Zhu, 2014). (Schefczyk's, 1993) marks a significant milestone in the field of aviation efficiency assessment as it represents the introduction of the use of Data Envelopment Analysis (DEA) for this purpose.

The objective of Schefczyk's study endeavor is to assess the 1990 efficiency of fifteen major international airlines using the CCR (Charnes, Cooper, Rhodes) input-oriented basic DEA model. The study demonstrated that DEA can be a very useful tool to assess the efficiency of international airlines which otherwise was difficult to do using financial data (Schefczyk's, 1993). (Fethi et al., 2000) and (Scheraga, 2004) also apply the CCR DEA model to evaluate the effectiveness of seventeen European airlines and thirty-eight worldwide carriers, respectively. While the latter covers the years 1995 and 2000, the former covers the years 1991 to 1995. (H. S. & Zhang, 2010) explored the efficiency of airlines operating both passenger and cargo divisions using data envelopment analysis (DEA) to investigate the potential benefits of a mixed passenger/freight airline engaging in a significant level of cargo business, seeking to determine if such operations lead to improved operational performance. There is a wealth of information available on the creation and use of DEA models. (Banker, 1984; Chen, 2021; Chang & Wang, 2020; Guo, Andersen & Petersen, 1993 & Cai, 2020; Lin, 2020; Lee et al., 2011). In this paper, this serves as a theoretical-methodological and empirical basis for evaluating the efficiency of five combination carriers using the DEA Super-Radial model.

Cargo operations, which are often referred to as air cargo operations, comprise a range of procedures and undertakings related to the transportation, handling and management of goods, packages and freight through air transportation networks. Transporting goods from continent to continent by air is the lifeline of global trade, enabling goods to be transported seamlessly and efficiently across continents. Air cargo is essential to international trade because it makes it possible to move products quickly and effectively across great distances. Air cargo, a crucial part of the larger logistics and supply chain sector, provides unmatched speed, dependability, and connection, making it essential for companies functioning in the current fast-paced global economy. Due to its ability to quickly reach locations globally, air cargo serves a wide range of sectors and markets, from perishable commodities that require speedy delivery to high-value items that require secure travel. Shippers, freight forwarders, and logistics companies reserve and book cargo space in advance, indicating the specifications of the cargo, including its weight, dimensions, and delivery requirements. Cargo is accepted and handled at the airport, where it is inspected and processed to make sure it complies with safety rules and paperwork requirements. Using specialized equipment, cargo handlers load and unload cargo into and off airplanes, enabling correct stowage and securement to prevent damage during transportation. Since freight must go through clearance procedures before it may cross international borders, compliance with customs laws and procedures is essential. Perishable products, electronics, medications, and automobile components are among the many items that airlines transport on scheduled and charter flights. Systems for tracking and tracing enable visibility and transparency to follow the location and status of cargo in real-time throughout the transportation process. Cargo handlers and ground transportation providers work together to unload, transfer, and distribute cargo to consignees at the destination airport. Strict implementation of screening protocols and surveillance systems are among the safety and security measures that protect goods against theft, tampering, and illegal access. Essentially, cargo operations are essential to the smooth functioning of supply chains and international trade because they provide quick, dependable, and cost-effective air cargo networks.

Global air carriers primarily engage in passenger transport operations; freight transport is often a lower priority or activity of lesser importance. Air freight transport does, however, often account for a sizable amount of earned income, particularly on long-haul routes (such as the Transatlantic, Europe-East Asia, and Transpacific), where revenue contributions might approach 20 percent (Abeyratne, 2012). According to the Morrell (2011) and the Boeing (2016), there is a growing trend in the transportation of air freight by the specialized freighter aircraft, with this volume share exceeding 50% worldwide. Air carriers may be categorized as follows based on the operating model used to carry out the air freight transport operations (Morrell, 2011; Abeyratne, 2012; Budd and Ison, 2017; Dresner and Zou, 2017):

Combination Carriers: These carriers' primary area of business is passenger air transportation, with air freight (sometimes known as "belly freight") transported in the lower deck compartment. The belly space of passenger aircraft (Zhang et al., 2004) accounts for more than half (55–60%) of this cargo volume, a rate that is expected to increase. It is possible to transport up to 30 tons of freight, particularly when wide-body aircraft (such as the Boeing 777 and the Airbus A330) are in use. Additionally, there are times when dedicated freighter aircraft—which typically make up a very tiny percentage of the airline fleet—are used to carry out air freight transport operations. Occasionally, a fully owned subsidiary engaged only in air freight transport (such as Singapore Airlines, Lufthansa Airlines, and Cathay Pacific Airlines) owns the specialized freighter aircraft. Consequently, by making sure that the existing freight capacity is adequately utilized, these carriers may increase their earnings to a large degree.

Freight-Only Carriers: These airlines (such as Cargolux Airlines, Nippon Cargo Airlines, and Aerologic Airlines) only operate dedicated freighter aircraft for the transportation of freight, they do not engage in passenger transport operations. Freight-only carriers typically rely on air freight forwarders to schedule and arrange freight shipments since they primarily concentrate on air freight transit without building adequate marketing skills. These planes feature wide doors and specialized equipment to ensure efficient carriage of cargo shipments. Cargo aircraft serve civil and military purposes, offering a versatile means of transporting various goods. Take the Boeing 747, for example, which can carry a substantial cargo load of approximately 1,13,000 kg. During cruise operations, this aircraft consumes around 10-11 tonnes of fuel per hour, translating to an average of 1 gallon of fuel burned per second. Despite this fuel consumption, the Boeing 747 boasts an impressive range of 7,790 nautical miles and has a fuel capacity of approximately 2,38,604 liters, emphasizing its capabilities in long-distance cargo transportation. (Salomon Marco, n.d.) Boeing 777F- has a maximum take-off weight of 7,66,000 pounds (3,47,450 kg), which means it can carry more than 2,26,000 pounds (102.8 metric tons) in revenue payload. (Clark, Jason S., and Kenneth D. Kirwan, n.d.)

Aircraft such as the B747, the B777, and the A321 are renowned for their superior fuel efficiency in comparison to other available aircraft models. This enhanced fuel efficiency makes them preferred choices for major airlines like Lufthansa airlines, Cathay Pacific airlines, Air China airlines, LATAM airlines and Air France KLM airlines. These airlines strategically opt for these aircraft types to optimize operational costs, reduce the environmental impact and enhance the overall performance. They demonstrate their global presence by operating a broad range of long- and short-haul flights, serving a variety of cargo markets globally. These airline choices are evidence of the continuous efforts that are made by the aviation industry to strike a balance between environmental responsibility and economic concerns since the emphasis on fuel efficiency is consistent with the industry's dedication to sustainability and cost-effective operations.

Continuous monitoring of the operational efficiency of five combination carriers is essential to driving future enhancements through targeted interventions. This foundational principle underscores the primary research hypothesis of this study. The research methodology revolves around the rigorous application of the DEA Super-Radial model, which serves as a pivotal tool in precisely evaluating the efficiency dynamics within the combination carrier sector. Through this model, the study discerns which carriers operate optimally and which require interventions to augment their performance. The empirical basis of this research draws from meticulous data collection, including annual reports from the carriers and other pertinent secondary sources. This approach ensures a comprehensive examination of the operational challenges and opportunities faced by the carriers, guiding strategic efforts to optimize efficiency and foster sustainable growth in the aviation industry.

The format of the remaining portion of the article offers a thorough and organized examination of the research. Section 2 provides a comprehensive analysis of the relevant literature, setting the stage by reviewing previous research and theoretical frameworks associated with Data Envelopment Analysis (DEA) and the Super Radial Model, with a focus on their use in assessing the effectiveness of DMUs in the aviation industry. This section justifies the need for the current study by highlighting significant gaps and shortcomings in the database of research, especially in the unexplored field of cargo operations and combination carriers. Section 3 describes in full the data analysis approach used. This section presents the Super Radial DEA model's application in detail, covering both the study's methodological stages and mathematical foundations. As part of its comprehensive assessment of the efficiency ratings for every DMU, Section 4 provides and examines the results of the analysis. In addition to comparing the effectiveness of different DMUs, this discussion highlights areas for improvement and best practices, placing the results in the larger perspective of resource management and cost control in aviation. By stressing the practical implications for airlines in optimizing their operations, Section 5 summarizes the study's major findings and contributions. The last Section 6 provides a thorough bibliography that strengthens the research's legitimacy and academic integrity by listing all the sources referenced in the article. This methodical technique guarantees a relevant narration that methodically walks the reader through the purpose, methods, conclusions, and significance of the study.\

RESEARCH METHODOLOGICAL FRAMEWORK

This research paper analyzes the operational efficiency of five leading combination carriers in the air cargo industry: Lufthansa, Cathay Pacific, Air China, LATAM, and Air France KLM. These airlines were selected for their significant global market presence, geographic diversity, and varied operational strategies, ensuring a comprehensive comparative analysis. Lufthansa, as a major European carrier, provides extensive global reach and high service standards. Cathay Pacific, a key player in the Asia-Pacific region, is known for its strategic efficiency. Air China represents China's growing influence in global trade. LATAM, the largest airline group in Latin America, ensures critical connectivity between South America and other continents. Air France KLM, combining the strengths of two major European airlines, offers extensive cargo services worldwide. The diverse geographic coverage and operational strategies of these airlines provide a robust dataset for identifying best practices and areas for improvement in the global air cargo industry.

The traditional Data Envelopment Analysis (DEA) framework is integrated with the Super Radial Model to assess the efficiency of decision-making units (DMUs). Due to this combination, a thorough evaluation of DMU efficiency is possible, considering both input and output variables. The technique by which observations are "enveloped" to provide a "frontier" for observational assessments that represent the performances of all entities under examination is known as "Data Envelopment Analysis" (DEA).

A popular technique for evaluating performance, DEA compares DMUs' efficiency to that of their peers to pinpoint areas for improvement and best practices. Conventional DEA models, such the CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper) models, assess DMUs according to their relative efficiency and differentiate between those that are performing at their highest level of efficacy and those that have space for development. Organizations may make well-informed decisions to improve their operational performance and have a deeper understanding of the DMUs' efficiency by employing the Super Radial Model inside the DEA framework. This method separates DMUs that function at their full efficacy from those that do not by evaluating them based on their relative efficiency.

Super Radial Model adds a strong methodological boost to the standard Data Envelopment Analysis (DEA) framework for evaluating the effectiveness of decision-making units (DMUs). Organizations may gain a better understanding of the complexity of DMU efficiency and capture super-efficiency by utilizing the Super Radial Model, which goes beyond the traditional DEA framework. This can provide insights into possible performance increases. This methodological development gives decision-makers the ability to identify effective DMUs and to find areas for resource reallocation and optimization, which in turn promotes organizational agility, resilience, and competitiveness in changing business settings. Because it allows for more thorough and useful evaluations of DMUs' efficacy and efficiency, the Super Radial Model's inclusion into DEA marks a significant advancement in performance evaluation approaches.

By offering the possibility to increase a DMU's efficiency without adversely affecting the performance of any other DMU, the Super Radial Model expands upon these basic models. By identifying inefficient components and offering suggestions for improving their efficiency while maintaining the system's overall performance, this advanced model offers a more detailed analysis.

This method provides a more thorough assessment of every DMU, allowing for a more thorough understanding of resource use and performance improvement. The inclusion of the Super Radial Model strengthens the DEA framework and makes it easier to make well-informed decisions and develop strategic plans. This improved analysis is especially helpful in the highly competitive and complicated industries like the aviation, where increasing efficiency may result in the significant cost savings and improved operational performance.

This research employs Data Envelopment Analysis (DEA), specifically the Super Radial Model incorporating both CCR and BCC approaches, to quantitatively assess the efficiency of five carriers in the aviation industry. By analyzing input-output relationships, the DEA Super Radial Model calculates efficiency scores for each carrier, providing quantitative performance indicators. In essence, it identifies units that exhibit superior efficiency relative to others operating at a similar scale. The Super Radial Model further enhances this by integrating super-efficiency as an additional criterion.

This research uses the DEA Super-Radial model to calculate the efficiency of five carriers. Assume that {DMU j (j = 1, 2..., n)} is one of n DMUs. Each produces a set of s outputs, Y rj (r =1..., s), by consuming a set of m inputs, X ij (i =1, 2..., m).

Drawing on the VRS (variable return to scale) model (Banker idr., 1984), the input-oriented VRS super-efficient efficiency assessment model has the following expression:

$$
\begin{aligned}
&\min \quad \theta \\
&\text{s.t} \sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j x_{ij} \leq \theta x_{ik}, \qquad i = 1, \ldots, m \\
&\sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j y_{rj} \geq y_{rk}, \qquad r = 1, \ldots, s \qquad (1) \\
&\sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j = 1 \\
&\lambda \geq 0, \quad j \neq k
\end{aligned}
$$

Figure 1. Shows Expression for calculations.

RESULTS AND DISCUSSION

The DEA Super-Radial model, which considers both constant and variable returns to scale, was utilized to assess airline efficiency when it came to input and output parameters. The number of aircrafts and the cost of fuel were the primary inputs used in this complete study. Because they are essential to the operational capacity and cost structure of airline operations, these inputs were chosen for analysis.

The relationship among the four DMUs—fuel cost in million, number of aircraft, cargo revenue tonne km (RFTK) million, and cargo carried tonnes (000)—is pivotal for assessing operational efficiency using Data Envelopment Analysis (DEA). Efficient DMUs achieve optimal efficiency by minimizing fuel costs while maximizing both cargo revenue tonne km and cargo volume, often with a leaner fleet of aircraft. Inefficient DMUs typically incur higher fuel costs and may underutilize their aircraft and cargo capacities. Non-efficient DMUs lie between efficient and inefficient groups, indicating opportunities for improving fuel cost management and optimizing aircraft and cargo utilization. Super-efficient DMUs stand out with remarkably low fuel costs and exceptional productivity in cargo revenue and volume, establishing performance benchmarks for others in the analysis. This nuanced understanding facilitates the identification of strategies to enhance overall efficiency and operational performance across various air cargo operations.

Cargo revenue tonne kilometres (RFTK) and cargo transported in tonnes were considered by the model on the output side. Cargo revenue tonne kilometres are an essential measure of the effectiveness and financial success of cargo operations as they represent the money made from moving cargo over a certain distance. Similarly, the cargo transported in tonnes shows the airline's ability to fulfill its freight needs by giving a clear indication of the volume of cargo handled.

Observed airlines for 2022–2023 are DMU units.

Table 1. Shows Input / Output Data for five airlines (2022-23)

DMU	(o)cargo revenue tonne km RFTK million	(o)cargo carried tonnes (000)	(I)fuel cost in million	(I)number of aircraft
Lufthansa	7913	811	8318	15
Cathay Pacific	738	1154	1341	20
Air France KLM	3645	472	7924	6
LATAM	353	900	1074	19
Air China	480	9843	3207	22
Total	13129	13180	21864	82

Note: I – input, O – output.

Source: Annual reports of respective airlines.

Table 2. Statistics of Input / Output elements for five airlines.

	Fuel cost in million	Number of aircraft	Cargo revenue tonne km (RFTK) million	Cargo carried tonnes (000)
Mean	4372.8	16.4	2625.8	2635.974
Median	3207	19	738	900
Std. Deviation	3149.876	5.678028	2909.54	3610.056
Minimum	1074	6	353	472
Maximum	8318	22	7913	9842.871

Table 3. Shows the Correlation (In this paper, all calculations and results are the author's.)

	Fuel cost in million	Number of aircraft	Cargo revenue tonne km (RFTK) million	Cargo carried tonnes (000)
Fuel cost in million	1	-0.76573	0.877301	-0.22982
Number of aircraft	-0.76573	1	-0.51722	0.542202
Cargo revenue tonne km (RFTK) million	0.877301	-0.51722	1	-0.39179
Cargo carried tonnes (000)	-0.22982	0.542202	-0.39179	1

The correlations in Table 3 provide valuable insights into the dynamics between operational costs, fleet size, and cargo performance metrics. The strong positive correlation between Fuel Cost and RFTK highlights the direct impact of fuel expenses on revenue generation from cargo operations. Meanwhile, the negative correlations, particularly between Fuel Cost and the Number of Aircraft, and between Number of Aircraft and RFTK, indicate areas where efficiency improvements and strategic adjustments could be made. Understanding these relationships helps airlines optimize resource utilization, manage costs more effectively and enhance overall operational performance in the cargo segment.

The findings of using the DEA Super Radial model of input and output orientation with constant return to evaluate the efficiency of carriers are displayed in Table 4 and Figures 2 and 3.

Table 4. Shows Five airlines respective efficiencies. Super Radial, or Super-CCR-I Constant and Super Radial (Super-CCR-O) returns to scale Returns on Scale: Fixed.

		Super-CCR-I + Super-Radial = DEA model Returns to Scale = Constant (0 < Sum of Lambda < Infinity).		Super-CCR-O + Super-Radial = DEA model Returns to Scale = Constant (0 < Sum of Lambda < Infinity).	
No.	**DMU**	**Score**	**Position**	**Score**	**Position**
1	**Cathay Pacific**	0.800396	4	0.800396	4
2	**Lufthansa**	2.038505	2	2.038505	2
3	**Air France KLM**	1.186912	3	1.186912	3
4	**LATAM**	0.567437	5	0.567437	5
5	**Air China**	7.580968	1	7.580968	1
	SD	2.621284		2.621284	
	Maximum	7.580968		7.580968	
	Minimum	0.567437		0.567437	

Average of Scores =	2.434844	2.434844
No. of efficient DMU=	0	0
No. of inefficient DMU=	5	5

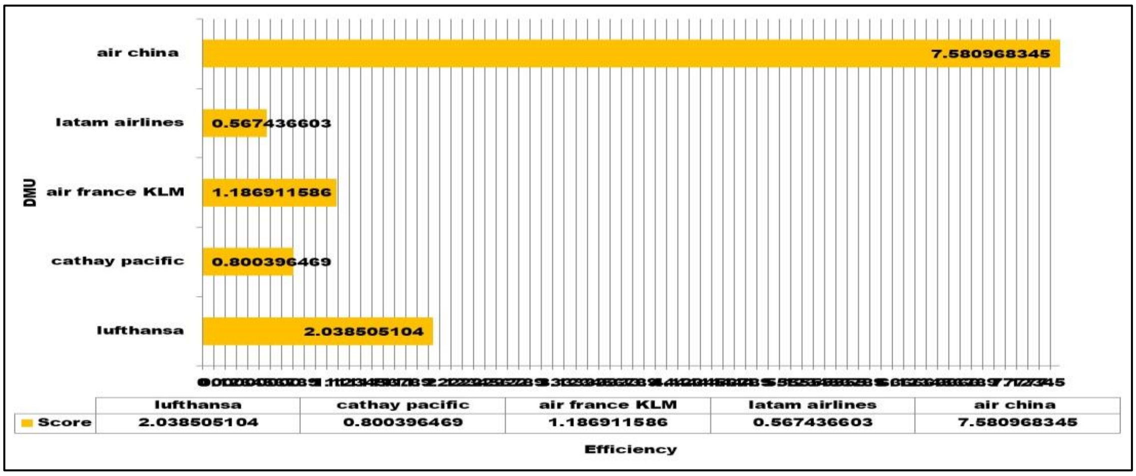

Figure 2: Shows the graph of efficiency scores of five airlines (Lufthansa, Cathay Pacific, Air China, LATAM and Air France KLM) using the Super-CCR-I, Super-Radial. (In this paper, all graphs are the author's.)

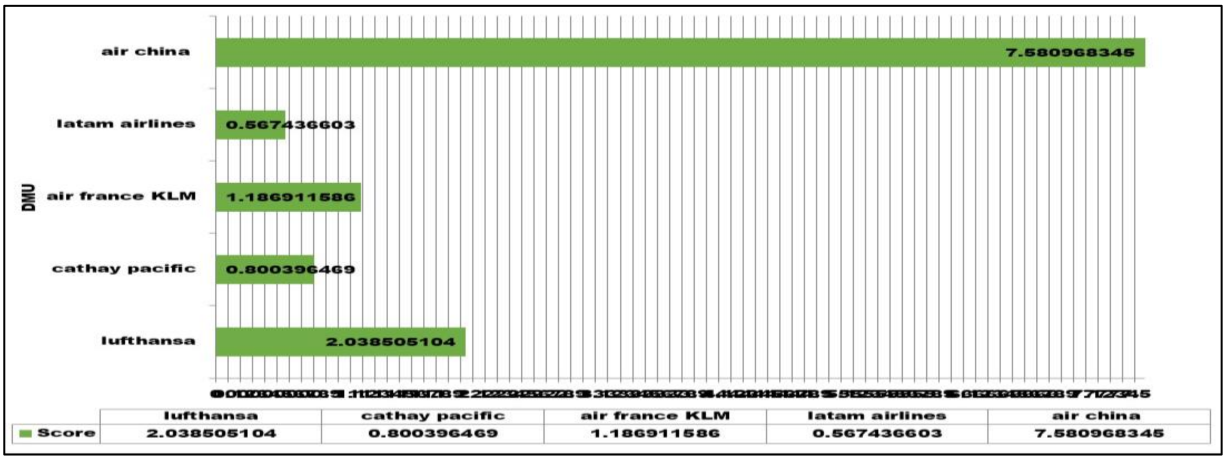

Figure 3. Shows the graph of efficiency scores of five airlines (Lufthansa, Cathay Pacific, Air China, LATAM and Air France KLM) using the Super-CCR-O, Super-Radial. (In this paper, all graphs are the author's.)

One of the most important metrics in Data Envelopment Analysis (DEA) for assessing a decision-making unit's (DMU) effectiveness is its efficiency score. When the DMU receives a score of one, it means that it is operating at its optimum efficiency, making use of all of its inputs to produce the highest number of outputs. If the score is higher than one, on the other hand, it indicates inefficiencies in the DMU and implies that it might produce even more with the same number of inputs. On the other hand, a score of less than one also denotes inefficiency because it means that the DMU is not making the most of its inputs to produce outputs that are comparable to those of the dataset's most efficient units.

In the CCR-I and the CCR-O input and output orientation models, CATHAY PACIFIC AIRLINES, the DMU unit, has a score value of 0.800396. This indicates 80% efficiency and 20% inefficiency of the DMU unit under consideration which is CATHAY PACIFIC. For other DMU units, the examination of the data is similar.

As per the Super-Radial (Super-CCR-I and Super-CCR-O) model outcomes, there were no carriers that demonstrated efficiency.

The findings of using the DEA Super-Radial model of input and output orientation with variable in the assessment of carriers' efficiency are displayed in Table 5 and Figures 4 and 5.

Table 5. Shows Five airline's levels of efficiency: Super Radial, or Super-BCC-I Super Radial (Super-BCC-O) with Variable Returns to Scale Returns on Scale: Not Fixed.

		Super-BCC-I, Super-Radial Model. Scale Returns = Variable (Sum of Lambda = 1)		Super-BCC-O, Super-Radial Model. Scale Returns = Variable (Sum of Lambda = 1)	
No.	**DMU**	**Score**	**Position**	**Score**	**Position**
1	**Lufthansa**	1	4	2.170919	2
2	**Cathay Pacific**	1.119342	3	1.197928	3
3	**Air France KLM**	2.499975	1	1	4
4	**LATAM**	1.248591	2	1	4
5	**Air China**	1	4	8.529351	1
	SD	0.57064		2.907431	
	Maximum	2.499975		8.529351	
	Minimum	1		1	
	Average of Scores =	1.373582		2.77964	
	No. of efficient DMUs=	2		2	
	No. of inefficient DMUs=	3		3	

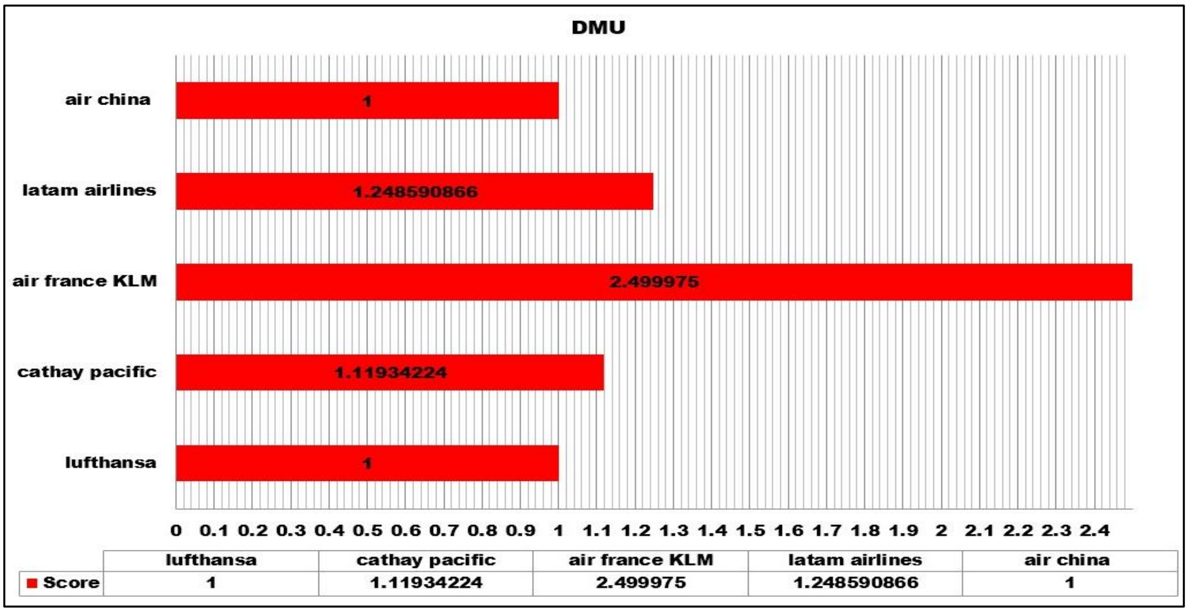

Figure 4. Shows the graph of efficiency scores of five airlines (Lufthansa, Cathay Pacific, Air China, LATAM and Air France KLM) using the Super-BCC-I, Super-Radial. (In this paper, all graphs are the author's.)

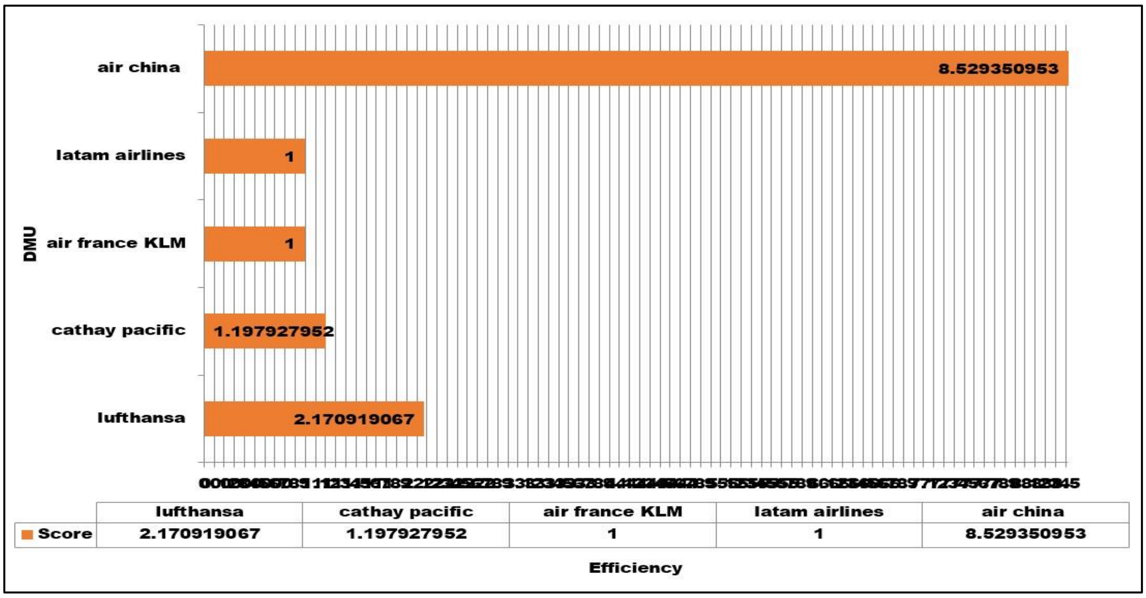

Figure 5. Shows the graph of efficiency scores of five airlines (Lufthansa, Cathay Pacific, Air China, LATAM and Air France KLM) using the Super-BCC-O, Super-Radial. (In this paper, all graphs are the author's.)

Based on the outcomes of the Super-Radial (Super-BCC-I), Lufthansa Airlines and AIR CHINA AIRLINES were the only two carriers that demonstrated efficiency. There were ineffective other carriers. The outcomes of using Super-Radial (Super-BCC-O) are the same. This technique indicated that just two carriers—Air France KLM Airlines and LATAM Airlines—were effective in the scenario. There were ineffective other carriers.

The percentage difference between the realized values and the projected values is displayed in the input/output element's projection. Table 6 exclusively displays the input/output element projection for the Super-Radial (Super-BCC-O) for the sake of example. This also applies to other Super-Radial models.

Table 6. Shows Super Radial (Super-BCC-O) is the projection of the input and output components. Super-BCC-O / Super-Radial is the DEA model for five airlines

			(I)fuel cost in million		(I)number of aircraft		(O)cargo revenue tonne km RFTK million		(O)cargo carried tonnes (000)	
No.	**DMU**	**Score**	**Projection**	**Change (%)**	**Projection**	**Change (%)**	**Projection**	**Change (%)**	**Projection**	**Change (%)**
1	**Lufthansa**	2.170919	7924	-4.74%	6	-60.00%	3645	-53.94%	472	-41.80%
2	**Cathay Pacific**	1.197928	1341	0.00%	18.8834	-5.58%	616.0638	-16.52%	963.3301	-16.52%
3	**Air France KLM**	1	7924	0.00%	6	0.00%	3645	0.00%	472	0.00%

4	**LATAM airlines**	1	1074	0.00%	19	0.00%	353.0115	0.00%	900	0.00%
5	**Air China**	8.529351	1341	-58.19%	20	-9.09%	738	53.75%	1154	-88.28%

To enhance efficiency, that is, to align the actual values of input/output elements with the projected ones, the DMU unit AIR CHINA AIRLINES must, for instance, to lower the fuel costs by 58.19%, decrease the number of aircraft by 9.09%, increase cargo revenue tonne-km by 53.75%, and carry 88.28% more cargo. Analyses of the input/output element projections for the other DMU units under observation are comparable.

"Slack" this term describes the capacity or resources that are underused inside a decision-making unit (DMU) in the context of Data Envelopment Analysis (DEA). It shows the possibility of enhancing efficiency by repurposing these underutilized resources to improve outputs while keeping inputs constant. Slack shows how to find and use unused resources more effectively to transform inefficient DMU units into efficient ones. Slack indicates that a DMU is not making the most of its inputs to produce the outputs as efficiently as possible.

Organizations may enhance their efficiency and streamline processes by identifying and resolving slack within DMUs. This process involves reallocating resources or adjusting operating procedures to use available inputs more effectively. By converting wasteful DMU units into effective ones (through Slack), organizations can enhance their productivity, reduce costs, and improve their competitive position in the market.

Table 7 only displays slack for the Super-Radial (Super-BCC-O) model for the sake of demonstration. The other Super-Radial models undergo comparable investigation.

Table 7. Shows the slacks for five airlines using Super-BCC-O, or Super-Radial, Slack Returns on Scale: Not Fixed.

No.	**DMU**	**Score**	***Excess***	***Excess***	***Shortage***	***Shortage***
			fuel cost in million	**number of aircraft**	**cargo revenue tonne km RFTK million**	**cargo carried tonnes (000)**
1	**Lufthansa**	2.170919	394	9	0	98.4255
2	**Cathay Pacific**	1.197928	0	.116597	0	0
3	**Air France KLM**	1	0	0	0	0
4	**LATAM airlines**	1	0	0	1.15E-02	0
5	**Air China**	8.529351	1866	2	681.7237	0

Therefore, for instance, the number of airplanes should be raised by nine, the cargo carried by 98.4 tonnes, and the fuel cost should be decreased by 394 in monetary units to convert the inefficient DMU unit Lufthansa Airlines into an efficient DMU unit. The other detected DMU units had comparable analyses.

It is vital to adjust to a dynamic and effective business environment, develop aircraft designs and materials to minimize weight, optimize flight paths, and use sustainable aviation fuels and fuel monitoring systems to enhance these carrier's efficiency. Operational methods must include predictive maintenance, dynamic scheduling, and efficient ground handling. The use of modular, inflatable cargo compartments might maximize available volume and minimize drag.

Participating in carbon offset programs, receiving training, and leveraging data analytics for in-the-moment decision-making may all help to further increase efficiency and lessen environmental effects.

CONCLUSION

Based on the findings derived from applying the DEA Super-Radial model to assess airline efficiency, several key insights emerge. Cathay Pacific Airlines demonstrated 80% efficiency in both the CCR-I and CCR-O models, suggesting potential for a 20% performance improvement, a pattern similarly observed across other carriers. None of the carriers achieved efficiency in the Super-CCR-I and Super-CCR-O models, indicating suboptimal utilization of inputs to produce outputs effectively. In contrast, Air China Airlines and Lufthansa Airlines were identified as efficient in the Super-BCC-I and Super-BCC-O models, highlighting their ability to convert inputs into outputs with minimal waste. Conversely, Latam Airlines and Air France KLM Airlines excelled inefficient resource utilization, optimizing inputs to achieve desired outputs with minimal waste.

Moreover, specific recommendations were provided to enhance efficiency among less efficient airlines, such as Air China Airlines reducing fuel costs, adjusting aircraft fleet size, optimizing cargo load, and increasing cargo revenue tonne-kilometers. This analysis offers a clear understanding of resource utilization efficiency, empowering airlines to allocate resources more effectively, reduce operational costs, and enhance profitability. These insights are critical for strategic planning, enabling airlines to implement targeted initiatives that improve overall efficiency and performance.

The study addresses a significant gap in efficiency assessments within the aviation sector, particularly for combination carriers that operate both passenger and cargo services. By employing the DEA Super Radial model, this research contributes a systematic approach to assessing and improving efficiency practices in the industry. It enhances understanding of the factors influencing airline efficiency and offers practical solutions for achieving operational excellence in a competitive and dynamic environment. Airlines can leverage these insights to strengthen their competitive position, achieve strategic goals, and contribute to a more sustainable and efficient aviation industry.

To further enhance efficiency, adopting a dynamic business environment, advanced aircraft designs to reduce weight and drag, optimizing flight paths and speeds, and implementing sustainable aviation fuels and fuel monitoring systems are recommended. Innovations such as modular, inflatable cargo holds could maximize space utilization and minimize drag. Operational strategies like dynamic scheduling, efficient ground handling, predictive maintenance, and leveraging data analytics for real-time decision-making are crucial. Training programs for efficient practices and participation in carbon offset programs can further improve efficiency and reduce environmental impact.

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