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Research Article

Prioritizing Growth Strategies in Aviation Sector: a Fuzzy DEMATEL Approach*

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Abstract: The prioritization of growth strategies in the aviation sector is crucial as the industry navigates evolving regulatory landscapes, operational challenges, and the long-term repercussions of the COVID-19 pandemic. This study employs the Fuzzy DEMATEL method to analyze the interdependencies among key strategic initiatives systematically, identifying Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER) as critical drivers of growth. The study is based on expert evaluations from Turkey, with nine experts selected based on their extensive professional experience in aviation sustainability, airport planning, regulatory policy, fleet operations, and strategic decision-making. Their experience levels range from 10 to 30 years, ensuring a comprehensive and informed assessment of growth strategies. Experts conducted pairwise comparisons to evaluate the influence of various strategic factors, with results analyzed using the Fuzzy DEMATEL approach to determine causal relationships among key strategies. Findings indicate that SAP, with the highest prominence and net causality scores, serves as a fundamental enabler for Energy Consumption Optimization (ECO), Post-COVID Recovery Strategies (PCRS), and Future Airport Planning (FAP). CER, ranking second in influence, significantly impacts SAP and ECO, reinforcing its role in regulatory compliance and operational efficiency. The study highlights that prioritizing SAP and CER enables aviation managers to align strategies with global sustainability objectives, optimize resource allocation, and enhance industry resilience. Furthermore, dependent strategies such as PCRS and FAP emerge as essential for recovery and long-term infrastructure development, yet their effectiveness is contingent on the successful implementation of SAP and CER. While the study is based on expert evaluations in Turkey, the methodology provides a replicable and applicable decision-making framework for international aviation management.

Keywords: Strategic Management, Aviation Management, Fuzzy Dematel
Jel Codes: M10, L93, C44

Havacılık Sektöründe Büyüme Stratejilerinin Önceliklendirilmesi: Fuzzy DEMATEL Yaklaşımı

Öz: Havacılık sektöründe büyüme stratejilerinin önceliklendirilmesi, sektörün değişen düzenleyici ortamlar, operasyonel zorluklar ve COVID-19 pandemisinin uzun vadeli etkileriyle başa çıkarken kritik bir öneme sahiptir. Bu çalışma, temel stratejik girişimler arasındaki karşılıklı bağımlılıkları sistematik olarak analiz etmek için Bulanık DEMATEL (Fuzzy DEMATEL) yöntemini kullanarak Sürdürülebilir Havacılık Uygulamaları (SAP) ve Karbon Emisyonlarının Azaltılması (CER) stratejilerini büyümenin en önemli itici güçleri olarak belirlemiştir. Çalışma, Türkiye'deki uzman değerlendirmelerine dayanmaktadır. Havacılık sürdürülebilirliği, havalimanı planlaması, düzenleyici politika, filo operasyonları ve stratejik karar alma alanlarında uzmanlaşmış dokuz uzman seçilmiştir. Uzmanların deneyim seviyeleri 10 ila 30 yıl arasında değişmekte olup, büyüme stratejilerinin kapsamlı ve bilinçli bir şekilde değerlendirilmesini sağlamaktadır. Uzmanlar, çeşitli stratejik faktörlerin etkisini değerlendirmek için çift yönlü karşılaştırmalar gerçekleştirmiş ve Bulanık DEMATEL yöntemi kullanılarak nedensellik ilişkileri analiz edilmiştir. Bulgular, SAP'nin en yüksek önem ve net nedensellik puanlarına sahip olduğunu ve Enerji Tüketiminin Optimizasyonu (ECO), COVID Sonrası İyileşme Stratejileri (PCRS) ve Gelecek Havalimanı Planlaması (FAP) için temel bir kolaylaştırıcı rol oynadığını göstermektedir. İkinci en etkili strateji olarak belirlenen CER, SAP ve ECO üzerinde önemli bir etkiye sahiptir, düzenleyici uyumluluğun sağlanması

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ve operasyonel verimliliğin artırılmasında kritik bir rol üstlenmektedir. Çalışma, SAP ve CER'ye öncelik verilmesinin, havacılık yöneticilerinin stratejilerini küresel sürdürülebilirlik hedefleriyle uyumlu hale getirmelerine, kaynak tahsisini optimize etmelerine ve sektörün dayanıklılığını artırmalarına olanak sağladığını ortaya koymaktadır. Ayrıca, PCRS ve FAP gibi bağımlı stratejiler, iyileşme ve uzun vadeli altyapı geliştirme açısından kritik bir rol oynamaktadır, ancak etkinlikleri büyük ölçüde SAP ve CER'in başarılı uygulanmasına bağlıdır. Çalışma Türkiye'deki uzman görüşlerine dayansa da kullanılan metodoloji uluslararası havacılık yönetimi için uygulanabilir, tekrarlanabilir bir karar alma çerçevesi sunmaktadır.

Anahtar Kelimeler: Stratejik Yönetim, Havacılık Yönetimi, Bulanık Dematel
Jel Kodları: M10, L93, C44

1. Introduction

The aviation sector plays a crucial role in global economic development, enabling trade, tourism, and international connectivity. However, the industry faces mounting pressures due to increasing environmental regulations, fluctuating fuel costs, and evolving consumer expectations in the post-pandemic era. These factors necessitate strategic innovation to ensure sustainable and resilient growth. The imperative to achieve carbon neutrality and reduce emissions, as outlined in international sustainability frameworks such as Carbon Neutral Growth from 2020 (CNG2020), further underscores the urgency for aviation stakeholders to align expansion efforts with global environmental objectives (Cui, Hu, & Yu, 2022). Simultaneously, regulatory and public scrutiny continue to push aviation companies toward adopting innovative and sustainable business models to remain competitive (Gössling & Humpe, 2023).

The COVID-19 pandemic introduced unprecedented disruptions to the aviation industry, causing significant declines in passenger traffic and revenue. Although recovery is underway, long-term resilience depends on how effectively aviation companies and policymakers integrate adaptive strategies into their decision-making processes. Airlines and airports must navigate shifting market dynamics, rapid technological advancements, and heightened competition while ensuring compliance with evolving sustainability mandates (Michelmann et al., 2023; Zhu et al., 2021). These interconnected challenges highlight the need for a structured decision-making approach to prioritize effective growth strategies.

This study aims to address the pressing need for strategic decision-making in aviation by prioritizing growth strategies using the Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) approach. The method systematically analyzes the interdependencies among key strategic initiatives, enabling decision-makers to distinguish between causative and dependent factors influencing growth. Unlike traditional prioritization models, Fuzzy DEMATEL accounts for the complexity of interrelations, offering a more nuanced and actionable framework.

A key contribution of this study lies in its expert-driven evaluation process, which ensures that findings are grounded in practical industry insights. The selection criteria for expert participation included extensive professional experience in aviation management, sustainability, airport planning, and regulatory policy, ensuring a comprehensive representation of sectoral perspectives. Nine experts from Turkey were chosen for their expertise in fleet operations, strategic decision-making, aviation sustainability, and infrastructure planning, with experience levels ranging from 10 to 30 years. Their assessments were used to construct an influence-relation matrix, revealing critical interdependencies among growth strategies.

While this study is based on expert evaluations from Turkey, its findings offer broader implications for global aviation management. The research aligns with international sustainability goals and regulatory frameworks, such as ICAO's CORSIA

(Carbon Offsetting and Reduction Scheme for International Aviation), which influences emissions reduction strategies worldwide. By identifying Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER) as key drivers of growth, this study provides insights applicable to aviation stakeholders beyond Turkey, particularly in regions where environmental regulations are becoming increasingly stringent. The structured approach presented here offers a replicable model for policymakers and industry leaders globally, reinforcing the need for integrated, sustainability-oriented decision-making in aviation growth strategies.

Research Questions and Study Scope

To achieve its objectives, this study is guided by the following research questions:

- What are the key growth strategies available to aviation companies?
- How do these strategies influence one another, and which are the most influential?
- Which strategies should be prioritized for long-term sustainable growth?

By addressing these questions, the study contributes to the literature on strategic aviation management by offering an empirical and methodological framework for prioritizing growth strategies. The research underscores the importance of aligning economic, operational, and sustainability goals to ensure that aviation sector growth remains resilient and adaptable to global challenges.

2. Literature Review

2.1 Sustainable Growth Strategies in Aviation

The aviation industry faces mounting pressure to adopt sustainable practices that balance operational growth with environmental responsibility. A comprehensive review by Afonso et al. (2023) highlights various strategies aimed at achieving sustainability in aviation, with a focus on both environmental and operational aspects. Key strategies include enhancing fuel efficiency through fleet modernization, exploring alternative fuel sources such as Sustainable Aviation Fuels (SAFs), and implementing carbon offset programs. These measures are critical in reducing the sector's environmental footprint, particularly in light of global climate targets. By transitioning to greener technologies and operational models, the aviation industry can mitigate its environmental impact while maintaining a competitive edge. However, these strategies must be integrated into business operations in a way that ensures long-term viability and efficiency.

In addition to technological advancements, the shift toward net-zero emissions requires a fundamental transformation of the aviation business model. Gössling and Humpe (2023) argue that sustainability must become a core principle within aviation logistics and operations, not merely an add-on to existing strategies. This approach includes exploring innovations such as electric and hybrid aircraft, which can significantly reduce emissions while maintaining operational capacity. The adoption of circular economy principles, wherein resources are reused and waste is minimized, also holds potential for sustainable aviation growth. Although these innovations offer promise, widespread implementation will require significant investment and policy support, both at national and international levels.

One of the most pressing challenges for the aviation industry is balancing the need to reduce carbon emissions with the goal of sustaining revenue growth. The Carbon Neutral Growth from 2020 (CNG2020) strategy, developed by the International Civil Aviation Organization (ICAO), provides a framework for achieving this balance by capping emissions at 2020 levels while allowing for continued industry expansion. Cui et al. (2022) conducted an empirical study that assessed the viability of this strategy, using data from 25 benchmarking airlines. Their findings suggest that while CNG2020 has the potential to drive carbon reduction efforts, achieving simultaneous revenue growth is heavily dependent on innovation and operational improvements. For instance, investments in fuel-efficient aircraft, improved air traffic management, and carbon offset programs can help mitigate the financial impact of adhering to carbon reduction mandates.

In this context, the aviation industry must strategically align its growth goals with environmental regulations to maintain profitability. Technological advancements, such as the development of more efficient engines and aircraft materials, will play a crucial role in enabling airlines to meet both revenue and carbon reduction targets. However, the challenge lies in ensuring that the adoption of these technologies is economically feasible for airlines, particularly those operating in cost-sensitive markets. Cui, Hu and Yu (2022) emphasize that the industry's ability to achieve sustainable growth will depend on its capacity to innovate and improve operational efficiency while remaining compliant with international carbon standards.

Optimizing energy consumption remains a crucial factor in achieving sustainable growth, particularly for aviation sectors in emerging markets. Orikpete et al. (2023) highlight the unique challenges faced by countries like Nigeria, where high fuel costs, outdated infrastructure, and weak regulatory enforcement hinder energy optimization efforts. In such regions, the cost of upgrading to more energy-efficient aircraft is often prohibitive, while existing airport infrastructure may not support the integration of renewable energy sources. Despite these challenges, there is potential for progress through targeted investments in energy-efficient technologies and the gradual implementation of renewable energy in airport operations.

Addressing these obstacles will require collaboration between government agencies, airlines, and international organizations. Policy interventions, financial incentives, and public-private partnerships could help accelerate the adoption of energy optimization strategies in emerging markets. Furthermore, Orikpete et al. (2023) suggest that regional efforts to improve regulatory oversight and create supportive policy frameworks could drive more sustainable practices across the aviation sector. Ultimately, a combination of technological innovation, operational efficiency improvements, and coordinated policy efforts will be necessary to overcome these challenges and foster long-term growth in the global aviation industry.

In conclusion, sustainable growth strategies in the aviation sector involve a complex interplay of technological advancements, operational efficiency, and regulatory compliance. The industry’s ability to reduce carbon emissions, optimize energy consumption, and maintain profitability hinges on its willingness to embrace innovation and align with global sustainability goals. Whether in developed or emerging markets, the aviation industry must navigate a range of challenges, but the path to sustainable growth remains achievable through collaboration, investment, and forward-thinking strategies.

2.2 Socio-Economic and Demographic Factors Affecting Aviation Growth

The growth of civil aviation is significantly shaped by socio-economic and demographic factors, which vary across different regions and market contexts. According to Addepalli et al. (2018), key drivers such as rising incomes, urbanization, population growth, and greater access to air travel are critical for the expansion of the aviation sector. In emerging economies like China and India, increasing middle-class populations and rising disposable incomes are driving a surge in demand for air travel. This phenomenon demonstrates how socio-economic advancements directly contribute to aviation growth, particularly in regions experiencing rapid economic development. Conversely, in mature markets, growth is often driven by demand for cost-effective travel solutions and greater international connectivity fueled by globalization and economic interdependence.

However, socio-economic factors alone cannot guarantee aviation growth, as infrastructure readiness plays an equally critical role. In regions with underdeveloped aviation infrastructure, socio-economic progress often fails to translate into sectoral growth. For example, Montsiemang and Dube (2023) argue that despite increased urbanization and rising income levels in some African nations, inadequate airport infrastructure and limited investment in aviation services hinder the sector's ability to meet rising demand. This highlights the necessity for alignment between socio-economic factors, government policies, and industry investments. Public-private partnerships, as emphasized by Addepalli et al. (2018), are vital for enhancing aviation infrastructure, especially in emerging markets where long-term growth opportunities remain untapped.

The role of aviation networks is also central to socio-economic development, particularly in facilitating connectivity and urban growth. Cristea (2023) highlights that aviation networks act as economic catalysts, attracting investments, stimulating trade, and promoting tourism. Well-connected airports significantly enhance accessibility to global markets, fostering regional integration and economic development. This impact is especially pronounced in remote or landlocked areas, where aviation serves as the primary connection to international economic hubs. For instance, Dubai and Singapore have leveraged aviation infrastructure to establish themselves as global economic powerhouses, demonstrating the transformative potential of well-developed aviation networks.

In addition to urban development, aviation networks support the growth of secondary cities by driving job creation, encouraging foreign direct investment, and promoting local tourism. Cristea (2023) illustrates how regional aviation networks in smaller cities can lead to substantial economic and social benefits, strengthening their role in regional integration. Similarly, Sun, Wandelt and Zhang (2023) emphasize the critical importance of aviation infrastructure in enabling these cities to capitalize on economic opportunities by improving their accessibility and attractiveness for global investments.

Environmental and socio-economic shifts are also reshaping demand patterns within the aviation sector. Ansell (2023) highlights that rising environmental awareness, particularly in developed economies, is influencing passenger preferences for sustainable aviation practices. Airlines are increasingly adopting biofuels and carbon offset programs to align with these changing demands, further demonstrating the interplay between socio-economic and environmental factors in shaping aviation strategies.

In summary, socio-economic and demographic factors, alongside aviation networks, are critical enablers of aviation growth and urban development. While rising incomes, urbanization, and population growth drive demand, the success of aviation growth is heavily dependent on the region's infrastructure and policy environment. Aviation networks not only promote economic activity but also significantly contribute to social development, reinforcing their role as essential components of regional growth strategies. Insights from Addepalli et al. (2018), Cristea (2023), Montsiemang and Dube (2023), and Ansell (2023) underline the importance of integrating socio-economic advancements with strategic investments to foster inclusive and sustainable aviation growth.

2.3 Strategic Decision-Making and Competitive Advantages in Aviation

Strategic decision-making is fundamental to sustaining a competitive advantage in the aviation industry, particularly in a rapidly evolving global environment. Managers increasingly rely on advanced methodologies to navigate the complexities of the sector, addressing challenges related to operational efficiency, safety, and sustainability. Among these methodologies, fuzzy logic has proven highly effective in handling uncertainty and interdependencies. Mızrak (2023) applied a fuzzy logic approach to analyze key human resource management criteria, such as employee performance and leadership effectiveness, offering aviation managers a nuanced framework for optimizing decisions in uncertain conditions. Similarly, Kumar, Rehman and Phanden (2024) demonstrated the utility of fuzzy DEMATEL in identifying and addressing human resource challenges, suggesting its broader applicability to strategic decision-making.

Machine learning techniques have also become indispensable for improving decision accuracy and agility in aviation. Cankaya et al. (2023) explored Bayesian inference as a tool for analyzing aviation incidents, enabling managers to implement data-driven safety protocols. Furthermore, Merlo (2024) discussed the use of predictive maintenance supported by artificial intelligence to enhance operational efficiency, highlighting its role in minimizing downtime and maximizing aircraft readiness. These advancements illustrate how integrating AI and machine learning into decision-making frameworks fosters agility in a highly dynamic environment.

Multi-criteria decision-making (MCDM) methods, particularly fuzzy DEMATEL, have grown in prominence for evaluating strategic objectives like cost efficiency, route optimization, and fleet expansion. Dožić (2019) underscored the value of MCDM in enabling managers to assess conflicting priorities effectively. Afonso et al. (2023) extended this perspective by emphasizing the role of sustainability-focused strategies, such as carbon neutrality initiatives, in aligning operational goals with regulatory and public expectations. These methodologies provide decision-makers with structured approaches to evaluate trade-offs and prioritize actions that enhance long-term competitiveness.

Strategic decision-making in the aviation sector extends beyond operational management to encompass critical areas such as maintenance, repair, and overhaul (MRO). Meissner, Rahn and Wicke (2021) highlighted the strategic importance of prescriptive maintenance strategies informed by simulation frameworks, which are particularly valuable in the post-COVID-19 recovery context. Liangrokapart and Sittiwatethanasiri (2023) argued that integrating digital technologies into MRO operations enables flexibility and innovation, ensuring competitiveness in the global market. Additionally, Heyes et al. (2023) emphasized that sustainability-driven strategic maintenance practices can significantly enhance airline reputations and operational efficiencies.

Environmental considerations are reshaping decision-making processes in aviation, as regulatory and public pressures demand greater alignment with sustainability goals. Cui, Hu, and Yu (2022) demonstrated the viability of achieving carbon emission reductions while maintaining revenue growth, underscoring the strategic importance of adopting sustainable business models. Afonso et al. (2023) highlighted that aligning aviation strategies with global sustainability frameworks, such as the CNG2020 initiative, is imperative for achieving long-term competitiveness in the industry.

In conclusion, strategic decision-making in aviation integrates advanced tools such as fuzzy logic, machine learning, and multi-criteria decision-making frameworks to navigate the complexities of a dynamic industry. These approaches empower managers to enhance operational efficiency, ensure safety, and align with sustainability objectives. The incorporation of advanced methodologies into areas like MRO operations and sustainability planning not only bolsters resilience but also ensures that the aviation sector remains competitive in an increasingly demanding global market.

2.4 Post-COVID Recovery and Future Prospects

The COVID-19 pandemic profoundly disrupted the global aviation industry, causing unprecedented reductions in air traffic, widespread fleet groundings, and substantial financial losses. Recovery efforts have emphasized resilience strategies that not only address immediate operational needs but also position the industry for long-term sustainability and preparedness for future crises. According to Zhu et al. (2021), global air transport recovery has been driven by policy interventions, including financial support packages, regulatory adjustments, and coordinated efforts to standardize health and safety protocols. These measures have enabled the industry to adapt to new challenges while maintaining essential services.

Beyond immediate recovery measures, resilience strategies must incorporate long-term perspectives. Michelmann et al. (2023) emphasize that digital transformation, cybersecurity investments, and flexible business models are critical for building resilience against future disruptions. Their study highlights the importance of integrating operational resilience with strategies to rebuild customer trust, ensuring a more robust aviation ecosystem. Similarly, Montsiemang and Dube (2023) argue that a comprehensive focus on recovery, resilience, and sustainability is vital for the sector's growth, particularly in regions heavily impacted by the pandemic.

Airports and airlines are also adapting their infrastructure and operational strategies to meet evolving post-pandemic demands. Serrano and Kazda (2020) examine how airports are redesigning facilities to comply with new health and safety regulations while adopting contactless services like automated check-in and biometric screening. These innovations have accelerated the use of digital technologies in airport operations, aligning with passenger expectations for enhanced safety and efficiency. Sun, Wandelt, and Zhang (2023) add that data-driven approaches are critical for understanding recovery trends, enabling stakeholders to plan future infrastructure investments effectively.

In terms of business models, the pandemic exposed the vulnerabilities of traditional revenue structures heavily reliant on passenger traffic and retail operations. Serrano and Kazda (2020) suggest that future airport planning should focus on diversifying revenue streams, such as expanding logistics and cargo services and forming partnerships with technology providers to enhance digital offerings. Heyes et al. (2023) also advocate for integrating sustainability into strategic planning, noting that environmental and social considerations are increasingly influencing stakeholder expectations and regulatory requirements.

Digital transformation has become a cornerstone of post-COVID recovery strategies. Merlo (2024) highlights the role of artificial intelligence in predictive maintenance, which enhances operational efficiency and reduces costs. Meanwhile, Singh et al. (2023) argue that the integration of sustainability initiatives with digital innovations, such as energy-efficient technologies, can simultaneously drive cost savings and align with global environmental goals.

In summary, the post-COVID recovery of the aviation sector requires a multifaceted approach emphasizing resilience, innovation, and sustainability. By adopting policies and technologies that ensure operational continuity during crises, diversifying revenue models, and investing in digital transformation, the industry can position itself for a more robust and adaptable future. Insights from the pandemic recovery process provide valuable lessons for navigating future challenges while fostering sustainable growth and innovation.

3. Methodology

3.1. Fuzzy DEMATEL Overview

The Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) is an analytical method used to model and analyze complex decision-making problems by visualizing the structure of interrelationships among factors. This method integrates fuzzy logic into the traditional DEMATEL approach, allowing for the handling of uncertainties and ambiguities in expert judgments, which are common when evaluating complex, interrelated criteria. In the context of strategic decision-making, Fuzzy DEMATEL helps decision-makers to not only understand the importance of each criterion but also to reveal the cause-and-effect relationships between them, thereby providing a clearer picture of how decisions influence one another.

Fuzzy DEMATEL operates by constructing a direct-influence matrix based on expert evaluations, where each pair of criteria is assessed in terms of how one criterion influences another. The use of fuzzy logic allows for more nuanced inputs, typically in the form of linguistic variables such as "very high influence" or "low influence," which are then converted into fuzzy numbers. This approach provides more flexibility and precision in capturing the subjective judgments of experts, especially in scenarios involving high uncertainty (Quezada et al., 2024). Once the influence matrix is developed, a total-relation matrix is calculated to identify the degree of interaction among the criteria. The results of the analysis can then be visualized through a cause-and-effect diagram, highlighting the driving and dependent factors that shape decision-making outcomes (Priyanka et al., 2023).

In the context of strategic decision-making, Fuzzy DEMATEL has been successfully applied in various industries to evaluate the interdependencies between strategic factors and to prioritize actions. For instance, Kumar, Rehman and Phanden (2024) used Fuzzy DEMATEL to strengthen social performance in Indian SMEs by analyzing key enablers in the digital era. Their study revealed the causal relationships among factors like technology adoption, employee skills, and operational efficiency, helping managers to prioritize initiatives that would have the most significant impact on social performance. Similarly, Saroha, Garg and Luthra (2022) applied the method to identify circular supply chain management practices for sustainability, showing how Fuzzy DEMATEL can uncover critical success factors in complex systems.

Raval, Kant and Shankar (2021) also demonstrated the utility of Fuzzy DEMATEL in their analysis of Lean Six Sigma implementation, where they used the method to analyze the interactions between critical success factors. By understanding which factors were the primary drivers of success, organizations were able to focus their efforts on the most impactful areas. Furthermore, in manufacturing strategies, Abdullah et al. (2022) employed Fuzzy DEMATEL to explore decisive factors in the adoption of Industry 4.0 technologies, offering insights into the dynamics between technological, operational, and managerial factors.

Overall, Fuzzy DEMATEL serves as a robust tool for strategic decision-making by allowing organizations to identify not only the relative importance of various criteria but also the causal pathways that shape their interactions. This holistic understanding enables managers to prioritize strategic actions more effectively, fostering better decision-making in complex and uncertain environments (Raval, Kant and Shankar (2021); Priyanka et al., 2023). Through its ability to handle vague and uncertain data, Fuzzy DEMATEL provides a structured approach to solving multi-criteria decision-making problems, making it highly applicable in fields such as manufacturing, human resources, and supply chain management (Quezada et al., 2024; Saroha, Garg and Luthra, 2022).

3.2. Data Collection

The data collection process for this study involves two main steps: the selection of growth strategies and evaluation criteria derived from the literature, and the selection of experts who provided pairwise comparisons using a Fuzzy DEMATEL approach.

Selection of Growth Strategies and Evaluation Criteria

The evaluation of growth strategies in the aviation sector is based on a set of criteria identified through an extensive literature review. These criteria are crucial to understanding the factors that influence sustainable growth and strategic decision-making in aviation. Key studies have identified essential growth strategies related to sustainability, operational efficiency, decision-making, and recovery planning (Afonso et al., 2023; Cui, Hu and Yu, 2022; Orikpete et al., 2023). Table 1 outlines the nine core criteria derived from the literature, which formed the basis of the pairwise comparisons made by the experts.

Table 1. Criteria Set

Criteria	Description	References
Sustainable Aviation Practices (SAP)	Practices aimed at reducing environmental impact through fuel efficiency and sustainable models.	Afonso et al. (2023); Gössling & Humpe (2023)
Carbon Emission Reduction (CER)	Strategies to reduce carbon emissions while maintaining revenue growth.	Cui, Hu and Yu, (2022); Ansell (2023)
Energy Consumption Optimization (ECO)	Adoption of energy-efficient technologies to reduce consumption.	Orikpete et al. (2023); Abdullah, Al-Ahmari and Anwar, (2022)
Demographic and Socio-Economic Drivers (DSED)	Factors like income levels, population growth, and urbanization that drive demand for air travel.	Addepalli et al. (2018); Cristea (2023)
Aviation Network Development (AND)	The role of aviation networks in fostering regional economic development and connectivity.	Cristea (2023); Giovanelli and Rotondo (2022)
Strategic Decision-Making (SDM)	Advanced decision-making frameworks using fuzzy logic and machine learning.	Mızrak (2023); Cankaya et al. (2023)
Maintenance and Safety (MS)	Ensuring operational continuity through strategic maintenance and safety practices.	Meissner et al. (2021); Liangrokapart and Sittiwatethanasiri (2023)
Post-COVID Recovery Strategies (PCRS)	Recovery readiness and resilience strategies after the COVID-19 pandemic.	Zhu et al. (2021); Michelmann et al. (2023)
Future Airport Planning (FAP)	Long-term airport infrastructure planning and development to meet future aviation demands.	Serrano and Kazda (2020); Heyes et al. (2023)

This set of criteria reflects the most significant aspects of aviation growth and recovery, providing a comprehensive framework for evaluating various strategies.

A total of nine experts from Turkey with substantial experience in the aviation sector were selected to participate in this study. The experts were chosen based on their extensive professional backgrounds in areas such as airport planning, sustainability, strategic decision-making, and maintenance. Their experience levels ranged from 10 to 30 years**,** ensuring that the data collected reflects a deep understanding of both strategic and operational aspects of the aviation industry. The experts were tasked with filling out pairwise comparison matrices to evaluate the influence of each criterion on the others. Table 2 summarizes the demographic information of the experts.

Table 2. Information about the Experts

Expert ID	Position/Title	Years of Experience
Expert 1	Senior Aviation Manager	18 years
Expert 2	Chief Engineer	22 years
Expert 3	Sustainability Director	15 years
Expert 4	Policy Advisor	20 years
Expert 5	Head of Airport Planning	25 years
Expert 6	Business Strategy Consultant	17 years
Expert 7	Fleet Operations Director	12 years
Expert 8	Academic Researcher	30 years
Expert 9	Regional Development Officer	10 years

The survey was conducted using a pairwise comparison approach, where experts rated the influence of each criterion on the others using a linguistic scale (e.g., No Influence, Low, Medium, High, Very High). These linguistic terms were then converted into fuzzy numbers to accommodate the subjective nature of expert opinions and to handle uncertainties inherent in decision-making (Kumar, Rehman and Phanden 2024; Raval, Kant and Shankar, 2021). The Fuzzy DEMATEL method was used to process these comparisons, constructing an influence-relation matrix that visualizes the causal relationships among the criteria.

3.3. Fuzzy DEMATEL Steps

The Fuzzy DEMATEL method consists of several structured steps that transform expert judgments into a usable framework for strategic decision-making. These steps include the fuzzification of expert judgments, the construction of the direct-relation matrix, and the computation of the influence-relation matrix. Each step involves mathematical operations to quantify and visualize the interdependencies between criteria.

Step 1: Fuzzification of Expert Judgments

The first step involves converting the expert assessments of the influence between criteria into fuzzy linguistic terms. This allows for the handling of subjective judgments, which often involve uncertainty. The experts use a linguistic scale to express their views on the degree of influence between criteria (e.g., No Influence, Low Influence, Medium Influence, High Influence, and Very High Influence). These linguistic terms are then mapped onto fuzzy triangular numbers.

These fuzzy numbers are used to form a fuzzy direct-relation matrix that captures the influence of each criterion on the others.

Step 2: Construction of the Direct-Relation Matrix

Once the fuzzification of expert judgments is completed, the next step is constructing the fuzzy direct-relation matrix $\tilde{A}$. This matrix represents the direct influence each criterion has on every other criterion, as assessed by the experts.

The matrix $\tilde{A}$ is structured as follows:

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{a}_{nn} \end{bmatrix} \tag{1}$$

where $\tilde{a}_{ij}$ represents the fuzzy value that denotes the direct influence of criterion i on criterion j. Diagonal elements $(\tilde{a}_{ii})$ are set to 0 , as no criterion influences itself.

Step 3: Defuzzification

Before calculating the total influence of the criteria, the fuzzy direct-relation matrix $\tilde{A}$ needs to be defuzzified to convert fuzzy numbers into crisp values. The most common defuzzification method is the centroid method, which calculates the crisp number a_{ij} from the fuzzy triangular number (l, m, u) using the following formula:

$$a_{ij} = \frac{l + m + u}{3} \tag{2}$$

This defuzzification process yields the crisp direct-relation matrix A, which represents the direct influence of each criterion on the others in a crisp numerical form.

Step 4: Normalization of the Direct-Relation Matrix

The direct-relation matrix A is then normalized to ensure that the values in the matrix are between 0 and 1 . The normalization is done using the following equation:

$$A^* = \frac{A}{\max\left(\sum_{j=1}^{n} a_{ij}, \sum_{i=1}^{n} a_{ij}\right)} \tag{3}$$

where A^* is the normalized direct-relation matrix. This step ensures that the influence values remain within a manageable range, with the maximum value being 1.

Step 5: Construction of the Total-Relation Matrix

After normalization, the total-relation matrix T is computed. The total-relation matrix accounts for both direct and indirect influences of the criteria on one another. It is calculated using the following equation:

$$T = A^*(I - A^*)^{-1} \tag{4}$$

where I is the identity matrix, and $(I - A^*)^{-1}$ represents the inverse of $I - A^*$. This matrix captures the complete system of interactions between the criteria, reflecting not only the direct relationships but also the indirect ones through intermediate criteria.

Step 6: Causal Diagram and Analysis

Finally, the values in the total-relation matrix T are used to construct a causal diagram, which visually represents the cause-and-effect relationships between the criteria. Two important measures derived from the total-relation matrix are:

Prominence $(r_i + c_i)$: The sum of the rows and columns for each criterion, representing the total level of interaction (both received and exerted influence) for that criterion.

Net Causality $(r_i - c_i)$: The difference between the sum of the rows and columns, indicating whether a criterion is a cause (positive value) or an effect (negative value).

Using these measures, the Fuzzy DEMATEL method provides a clear understanding of which criteria are the key drivers (causes) and which are dependent (effects) in the system, helping to prioritize strategic actions.

3.4. Data Analysis

In this section, the focus is on how the causal diagrams will be generated and interpreted to provide meaningful insights into the interrelationships between the selected criteria for growth strategies in the aviation sector. The Fuzzy DEMATEL method produces a total-relation matrix, which forms the basis for generating these causal diagrams.

Step 1: Deriving the Prominence and Net Causality

Once the total-relation matrix (T) is computed, two key indicators are derived for each criterion: prominence and net causality.

Prominence is calculated as the sum of both the row and column values for each criterion in the total-relation matrix. The row sum (r_i) represents the total influence a criterion exerts on others, while the column sum (c_i) represents the total influence it receives. The formula for prominence is:

$$\text{Prominence } (r_i + c_i) = \sum_{j=1}^{n} t_{ij} + \sum_{j=1}^{n} t_{ji} \tag{5}$$

This value indicates how involved a particular criterion is within the system, revealing whether it is a critical driver of the overall process.

Net Causality is calculated as the difference between the row sum and the column sum:

$$\text{Net Causality } (r_i - c_i) = \sum_{j=1}^{n} t_{ij} - \sum_{j=1}^{n} t_{ji} \quad (6)$$

This value distinguishes causal criteria (those with positive net causality) from effect criteria (those with negative net causality). Causal criteria are those that influence others significantly, while effect criteria are more influenced by other factors.

Step 2: Constructing the Causal Diagram

Based on the prominence and net causality values, a causal diagram is created. This diagram is a two-dimensional plot where:

The **x**-axis represents the net causality $(r_i - c_i)$, indicating whether a criterion is more of a cause (positive value) or an effect (negative value).

The y -axis represents the prominence $(r_i + c_i)$, indicating the overall influence (both exerted and received) of each criterion in the system.

Each point on the diagram corresponds to one of the criteria, with its position determined by its net causality and prominence values.

4. Results

4.1. Influential Strategies

Based on the results of the Fuzzy DEMATEL analysis**,** several key strategies have been identified as the primary drivers of growth in the aviation sector. These strategies exhibit positive net causality**,** meaning they exert substantial influence over other criteria and are critical levers for strategic decision-making.The most influential strategy in the analysis is Sustainable Aviation Practices (SAP)**.** This strategy is central to the aviation sector's long-term success, as it focuses on reducing environmental impact, improving fuel efficiency, and adopting sustainable aviation fuels. As seen in the causal diagram (Figure 1) SAP occupies a position of high net causality (positive values), making it a major driver of other strategies such as Carbon Emission Reduction (CER) and Energy Consumption Optimization (ECO)**.**

Carbon Emission Reduction (CER) also emerges as a highly influential strategy. As aviation industries worldwide face increasing regulatory pressure to reduce their carbon footprints, CER becomes a key component of any sustainable aviation growth plan. The high prominence of CER in the total-relation matrix reflects its interaction with other critical areas, such as Post-COVID Recovery Strategies (PCRS) and Future Airport Planning (FAP)**.** The total-relation matrix (Table 3) shows how these influential strategies exert both direct and indirect impacts on other growth strategies. For instance, improvements in SAP significantly drive advancements in ECO, as both strategies are aligned with achieving operational efficiency and reducing environmental harm.

Table 3. Total-Relation Matrix of Influential Strategies

	SAP	CER	ECO	DSED	AND	SDM	MS	PCRS	FAP
SAP	1.511129	1.604149	1.613920	1.323741	1.621505	1.568522	1.629288	1.702599	1.680030
CER	1.604149	1.503977	1.623284	1.315497	1.610631	1.558973	1.633572	1.698613	1.670294
ECO	1.613920	1.623284	1.529564	1.332177	1.619564	1.570424	1.649545	1.711133	1.691404
DSED	1.323741	1.315497	1.332177	1.035479	1.344273	1.285466	1.351714	1.406197	1.387641
AND	1.621505	1.610631	1.619564	1.344273	1.528667	1.575841	1.634119	1.715668	1.689082
SDM	1.568522	1.558973	1.570424	1.285466	1.575841	1.529601	1.599634	1.664338	1.644821
MS	1.629288	1.633572	1.649545	1.351714	1.634119	1.599634	1.682208	1.743411	1.720991
PCRS	1.702599	1.698613	1.711133	1.406197	1.715668	1.664338	1.743411	1.827038	1.796852
FAP	1.680030	1.670294	1.691404	1.387641	1.689082	1.644821	1.720991	1.796852	1.772072

4.2. Dependent Strategies

While some strategies act as key drivers, others are more dependent on changes driven by the influential strategies. These effect strategies exhibit negative net causality, indicating that they are outcomes of systemic changes rather than initiators.For instance, Post-COVID Recovery Strategies (PCRS) ranks as one of the most dependent strategies. The analysis suggests that PCRS is significantly influenced by other strategies, particularly CER and SAP. As seen in the causal diagram, PCRS falls on the left side of the x-axis (negative net causality), meaning that while it plays a crucial role in the overall recovery and resilience of the aviation industry, its success is contingent on the effectiveness of sustainability and emission reduction efforts.

Future Airport Planning (FAP) is another dependent strategy identified in the analysis. FAP is deeply influenced by the implementation of Strategic Decision-Making (SDM) and Maintenance & Safety (MS) strategies, highlighting how airport infrastructure and operational decisions are shaped by broader trends in aviation technology and regulatory environments. Table 4 illustrates dependent strategies and their interdependencies.

Table 4. Dependent Strategies and Their Interdependencies

	SAP	CER	ECO	DSED	AND	SDM	MS	PCRS	FAP
SAP	0.511129	0.604149	0.613920	0.323741	0.621505	0.568522	0.629288	0.702599	0.680030
CER	0.604149	0.503977	0.623284	0.315497	0.610631	0.558973	0.633572	0.698613	0.670294
ECO	0.613920	0.623284	0.529564	0.332177	0.619564	0.570424	0.649545	0.711133	0.691404
DSED	0.323741	0.315497	0.332177	0.035479	0.344273	0.285466	0.351714	0.406197	0.387641
AND	0.621505	0.610631	0.619564	0.344273	0.528667	0.575841	0.634119	0.715668	0.689082
SDM	0.568522	0.558973	0.570424	0.285466	0.575841	0.529601	0.599634	0.664338	0.644821
MS	0.629288	0.633572	0.649545	0.351714	0.634119	0.599634	0.682208	0.743411	0.720991
PCRS	0.702599	0.698613	0.711133	0.406197	0.715668	0.664338	0.743411	0.827038	0.796852
FAP	0.680030	0.670294	0.691404	0.387641	0.689082	0.644821	0.720991	0.796852	0.772072

4.3. Strategy Prioritization

To prioritize the strategies, we utilize the prominence and net causality values calculated earlier. These values are used to rank strategies based on their overall impact and involvement in the system. The prominence values represent the total level of interaction a strategy has with others, making it a key indicator of the strategy's centrality in decision-making. On the other hand, net causality helps distinguish whether a strategy is more of a cause or an effect in the system. Based on these metrics, the following strategies have been identified as the top priorities for growth in the aviation sector:

Sustainable Aviation Practices (SAP): Ranked highest in both prominence and net causality, SAP should be the cornerstone of any aviation growth strategy. Its role in driving both environmental and operational efficiency makes it a vital component.

Carbon Emission Reduction (CER): Close behind SAP, CER plays a critical role in ensuring long-term regulatory compliance and sustainability. It is highly interactive with other strategies and should be prioritized for resource allocation. Energy Consumption Optimization (ECO): While not as causal as SAP or CER, ECO still holds significant prominence, particularly due to its alignment with broader sustainability goals. It requires careful planning to complement the implementation of CER.

The causal diagram (Figure 1) visually represents these findings, highlighting which strategies should be prioritized based on their prominence and net causality. SAP, for example, sits high on the prominence scale with strong causality, while strategies like PCRS and FAP, although important, are shown to be more dependent on the success of others.

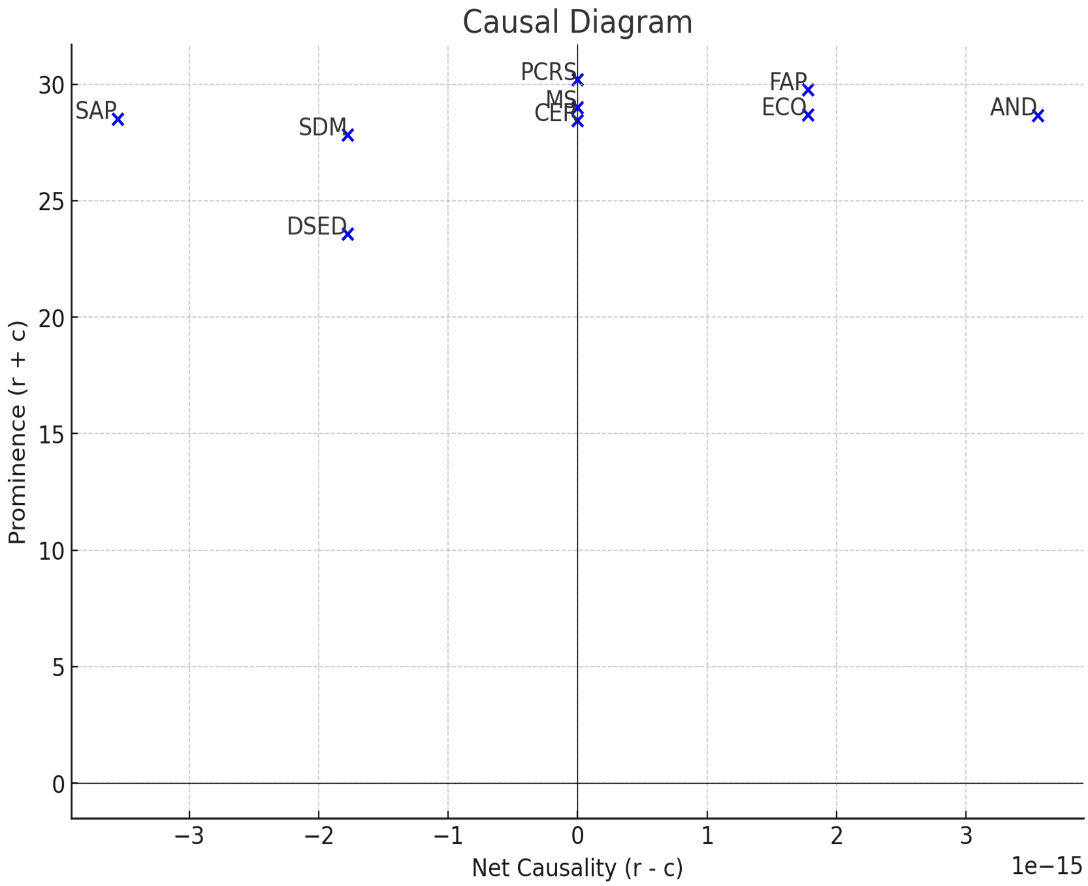

Figure 1. Causal Diagram of Growth Strategies in Aviation

The analysis reveals that Sustainable Aviation Practices and Carbon Emission Reduction are the most influential strategies driving growth in the aviation sector. By prioritizing these strategies, decision-makers can ensure the long-term success and sustainability of aviation operations. Meanwhile, dependent strategies like Post-COVID Recovery and Future Airport Planning must be carefully monitored to ensure they adapt to broader systemic changes. The integration of these findings into strategic planning will allow for the effective allocation of resources and ensure that aviation growth is aligned with both sustainability goals and operational efficiency.

5. Discussion

The findings from the Fuzzy DEMATEL analysis provide critical insights into which strategies should be prioritized for driving growth in the aviation sector. The results highlight Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER) as the most influential strategies. These two strategies not only exhibit high net causality but also interact strongly with other growth factors, making them primary drivers of sustainable growth. SAP, for instance, is central to achieving long-term environmental and operational sustainability, as it directly influences Energy Consumption Optimization (ECO) and Post-COVID Recovery Strategies (PCRS). Similarly, CER is essential for compliance with global environmental regulations, which has a ripple effect on the broader aviation ecosystem. The prioritization of these strategies is essential because they are foundational for aligning growth with sustainability goals, operational efficiency, and regulatory requirements. Other dependent strategies, such as Future Airport Planning (FAP), while critical, are more influenced by the successful implementation of SAP and CER, indicating that their outcomes hinge on the effectiveness of these key drivers.

From a practical standpoint, the analysis offers several actionable recommendations for aviation managers and decision-makers. First and foremost, allocating resources to strategies with high prominence, such as Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER), is crucial. These strategies not only have a direct and significant impact on other growth initiatives but are also foundational to the long-term sustainability of the aviation sector. SAP, for example, encompasses the adoption of sustainable fuels, improvements in operational efficiency, and reducing the overall carbon footprint, which are essential for complying with both current and future environmental regulations. As global pressure mounts for industries to address climate change, SAP's implementation becomes a non-negotiable aspect of any aviation company’s strategic roadmap. CER, similarly, addresses a critical global priority—achieving net-zero emissions—which requires consistent investment in technology, operational changes, and innovation. By prioritizing these strategies, managers can ensure their companies stay ahead of regulatory changes, enhance their reputation for environmental responsibility, and maintain competitive advantages in a rapidly changing industry.

Furthermore, dependent strategies like Post-COVID Recovery Strategies (PCRS) and Future Airport Planning (FAP) must be integrated into broader, long-term strategic plans to ensure these areas are adaptable to the changes initiated by SAP and CER. PCRS, for instance, deals with restoring airline operations, reconfiguring passenger demand, and addressing the altered landscape of air travel post-pandemic. However, its success depends heavily on the implementation of SAP and CER, which ensure that recovery efforts align with sustainability targets. Without alignment, recovery efforts may be short-lived or inefficient. Managers need to create flexible frameworks within their strategic plans that allow PCRS to evolve in response to regulatory changes and environmental sustainability goals. Future Airport Planning (FAP), which involves upgrading airport infrastructure to accommodate future demand, must also consider advancements in sustainable aviation technologies and the operational shifts prompted by emissions reduction strategies. This includes incorporating green technologies in airport design, enhancing energy efficiency, and developing infrastructure that supports the integration of electric or hydrogen-powered aircraft in the future.

Second, decision-makers should focus on continuous improvement and monitoring of supporting strategies such as Energy Consumption Optimization (ECO). Although not as prominent or causal as SAP and CER, ECO plays a vital role in the aviation sector's overall push toward greater efficiency. ECO initiatives include optimizing fuel usage, improving aircraft design to reduce drag, and enhancing ground operations to minimize energy waste. These efforts complement SAP and CER by providing the technical means to achieve lower energy consumption, which directly impacts cost savings and environmental performance. Managers should therefore invest in technologies and operational changes that enable continuous monitoring and optimization of energy use. This could involve deploying real-time data analytics to track fuel consumption, integrating artificial intelligence to predict optimal flight routes, or investing in research and development for more fuel-efficient aircraft designs. While SAP and CER drive the broad agenda, ECO ensures the aviation industry meets its efficiency targets along the way.

Third, aviation managers must recognize that while dependent strategies such as PCRS and FAP may not be the primary drivers of change, they are essential for ensuring resilience and operational continuity. In the context of post-pandemic recovery, the aviation industry has had to navigate unprecedented challenges, from fluctuating passenger demand to supply chain disruptions. As such, PCRS is critical for rebuilding and future-proofing the industry against similar crises. The key to success lies in aligning PCRS with sustainability efforts like SAP and CER. By doing so, companies can not only recover but also set the stage for long-term resilience and growth. Moreover, future airport planning should not only accommodate growing passenger numbers and larger aircraft but also anticipate the infrastructure needs of an increasingly sustainable aviation industry. This might involve planning for airports capable of supporting electric planes or incorporating energy-efficient building technologies.

The prioritization of highly influential strategies like SAP and CER ensures that aviation companies can meet their sustainability targets, maintain compliance with environmental regulations, and secure a competitive advantage. Meanwhile, the integration of dependent strategies like PCRS and FAP into a cohesive, forward-looking strategy ensures that the sector remains resilient and agile in the face of future challenges. By continuously improving energy optimization efforts and aligning recovery and planning strategies with broader sustainability goals, aviation managers can position their companies for long-term success in an industry that is undergoing rapid and profound transformation.

The findings of this study align with existing literature, particularly the work of Afonso et al. (2023), who identified sustainability as a core component of future aviation growth. The results also support the conclusions of Cui et al. (2022), which emphasized the importance of balancing carbon emission reduction with revenue growth. However, this study goes beyond prior research by integrating the interdependencies between these strategies through a structured Fuzzy DEMATEL approach, offering a clearer understanding of how these strategies interact. While previous studies have focused on individual strategies in isolation, this analysis provides a holistic view of how multiple strategies work together, influencing both direct and indirect growth drivers in the aviation sector.

6. Conclusion

This study identified and prioritized key growth strategies in the aviation sector using the Fuzzy DEMATEL method, with a particular focus on understanding the interdependencies between sustainability, operational efficiency, and post-pandemic recovery efforts. The analysis highlighted Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER) as the most influential strategies, playing a pivotal role in driving other critical areas such as Energy Consumption Optimization (ECO), Post-COVID Recovery Strategies (PCRS), and Future Airport Planning (FAP). These strategies are essential for ensuring the long-term sustainability and operational success of the aviation industry, especially in light of global environmental regulations and evolving consumer demands.

From a theoretical standpoint, this study contributes to strategic management by demonstrating how Fuzzy DEMATEL can be applied to complex, multi-criteria decision-making processes. The use of this methodology enabled a clearer understanding of how different strategies interact, providing a systematic approach to identifying both causal and dependent factors within the aviation sector. In practice, the study offers aviation managers actionable insights into resource allocation, strategy prioritization, and the importance of aligning recovery and sustainability efforts. By focusing on the most influential strategies, decision-makers can enhance operational efficiency, meet regulatory standards, and build resilience against future disruptions.

However, the study is not without limitations. The reliance on expert opinion introduces a degree of subjectivity, and while the experts selected are knowledgeable in the field, their views may reflect specific regional or industry biases, particularly since the study is focused on the Turkish aviation sector. Additionally, the analysis is limited to a snapshot in time, and as the aviation sector continues to evolve, future research could explore how emerging technologies, such as electric or hydrogen-powered aircraft, will influence strategic priorities. Future research could also expand the scope to include a more diverse set of stakeholders and regions to enhance the generalizability of the findings. Moreover, integrating quantitative data alongside expert assessments could provide a more robust analysis of strategy performance over time. Despite these limitations, this study provides a valuable framework for strategic decision-making in aviation and offers a roadmap for future research and industry application.

In addition to identifying key growth strategies, this study offers several practical implications for aviation managers and decision-makers. First, the prioritization of Sustainable Aviation Practices (SAP) and Carbon Emission Reduction (CER) should guide resource allocation and strategic focus, as these strategies are not only critical for achieving sustainability targets but also drive operational efficiencies across the sector. Energy Consumption Optimization (ECO), while not as prominent, plays a supporting role and should be continuously monitored and improved to ensure alignment with broader sustainability efforts.

Post-COVID Recovery Strategies (PCRS) and Future Airport Planning (FAP), though more dependent on other factors, remain crucial for ensuring resilience and operational continuity. Integrating these dependent strategies into broader strategic frameworks allows the aviation sector to remain adaptable in the face of evolving industry demands, particularly as the recovery from the pandemic continues. Decision-makers must recognize that recovery and future planning should evolve in response to sustainability initiatives to ensure long-term success.

In summary, the findings emphasize the need for a balanced approach, where both high-priority, causal strategies and dependent, supporting strategies are considered together in strategic planning. This holistic view allows aviation managers to drive sustainable growth, remain competitive, and future-proof their operations in a rapidly changing global landscape.

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