The development and resilience of Indian aviation industry in pre-and post-COVID-19 era

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Dedication

To our precious Shanaya, whose tender word, "Acha" is the most beautiful sound in my world, and whose love inspires me every day.

Abstract

The Indian aviation industry has undergone significant transformation and growth, particularly since the entry of low-cost carriers (LCCs) in 2003. With expansive geography, a rising middle class, liberalisation policies, and consistent GDP growth, India offers fertile ground for aviation to thrive. Projected to be among the world's top economies by 2030, aviation's role in connectivity and development will only expand. Despite this potential, persistent challenges remain—airline bankruptcies, high operating costs, and low revenues. Industry consolidation and privatisation of the national carrier have reshaped the competitive landscape. In response, the government implemented reforms like easing entry barriers, allowing foreign direct investment (FDI), and launching the National Civil Aviation Policy (NCAP). Among these, the UDAN (Ude Desh ka Aam Naagrik meaning "*Let the common citizen of the country fly*") scheme is notable for enhancing regional connectivity by reviving underserved airports and stimulating Tier 2 and Tier 3 economies. However, the COVID-19 pandemic introduced a sudden structural shock, severely disrupting aviation operations and exacerbating sectoral vulnerabilities. This PhD thesis investigates three interrelated dimensions of Indian aviation using a multi-method approach. Chapter 1 explores key drivers of airline revenues between 2007 and 2022, revealing a strong revenue–expenditure link, where higher spending correlates with increased passenger volumes and staffing. It also examines how ownership, business models, and regional connectivity influence financial outcomes. Chapter 2 analyses the resilience of India's ten busiest airports from 2016 to 2024, with a focus on the pandemic years. Using the Bayesian vector autoregression (BVAR) model, it compares predicted and actual volumes of passengers and cargo. Findings suggest airports with better infrastructure showed greater resilience, though even major hubs experienced declines. The chapter calls for improved infrastructure, better cargo operations, and adaptive resilience strategies aligned with global protocols, such as those from the International Civil Aviation Organization (ICAO) and the World Health Organization (WHO), to prepare for future disruptions. Chapter 3 presents stakeholder perspectives—airlines, airports, regulators, and travel agents—on the implementation and sustainability of the UDAN scheme. Key barriers identified include poor infrastructure, bureaucratic delays, weak state-level support, and fragmented coordination among stakeholders. Together, these studies offer comprehensive insights into Indian aviation's evolving landscape. The thesis provides evidence-based recommendations to support sustainable policy, boost airport resilience, and enhance stakeholder cooperation—ultimately fostering balanced and long-term sectoral growth.

Acknowledgements

सर्वं विद्या तपोमूलं सर्वं विद्या फलोद्गमम्।

विद्या सारतमं लोके विद्या सर्वत्र पूज्यते॥

All virtues stem from knowledge, and all success arises from it.

Knowledge is the essence of the world, and it is revered everywhere.

Undertaking this PhD has been a test of resilience and perseverance, made possible by the unwavering support of my dedicated supervisors and the School of Aviation at Massey University, New Zealand. This journey, though arduous, has been made possible by the collective efforts of those who have stood by me, and for that, I am truly thankful.

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Introduction

The aviation sector is a vital enabler of economic growth, not only facilitating the movement of passengers and cargo but also fostering tourism, attracting investment, and driving regional development (Bråthen & Halpern, 2012; ICAO, 2017; Salesi et al., 2021). Over the past two decades, India's aviation industry has emerged as one of the most dynamic globally, driven by the proliferation of low-cost carriers (LCCs) and the diversification of business models. This rapid growth has resulted in a significant increase in passenger traffic, aircraft orders, and market competitiveness (Jain & Natarajan, 2015). According to O'Connell et al. (2013) these developments in India can be attributed to favourable demographics, a burgeoning middle class with rising disposable income fuelling tourism, and governmental policies that simplify regulations, encouraging private airlines to overcome hurdles that once stymied sectoral growth. This policy shift has laid the groundwork for transformative initiatives such as India's regional connectivity scheme (RCS), which seeks to improve accessibility to both unserved and underserved airports across the country. By doing so, the scheme aims to foster regional integration and stimulate broader economic development. Despite these advancements, the sector faces persistent challenges. Elevated operating costs and relatively low revenue margins have led to financial distress and insolvencies among multiple carriers, including the once-dominant state carrier Air India[1], which was fully privatised after decades of monopoly (Saranga & Nagpal, 2016; Singh et al., 2019). Additionally, external shocks such as the global financial crisis and the COVID-19 pandemic have underscored the sector's vulnerability to exogenous forces (see Serrano & Kazda, 2020; Wu et al., 2025). Understanding how the Indian aviation sector has evolved in terms of operational resilience, financial performance, and

[1] Originally launched by Tata in 1932, Air India was nationalised more than 20 years later. It operated a domestic monopoly for decades until India liberalised its economy in the early 1990s, ushering in fierce competition that cut into Air India's market share (Kay, 2024).

regional connectivity (UDAN) is crucial for ensuring the long-term sustainability of the industry. This is especially significant as India emerges as a pivotal global aviation market, with its continued growth expected to play a key role in supporting the country’s economic and social development.

The first chapter in this thesis investigates the revenue dynamics of Indian airlines, focusing on the interplay between revenue generation and expenditure components. While the growth of the aviation sector has created a competitive and vibrant market, financial sustainability remains a critical concern (Singh et al., 2019). This thesis examines key variables, including staff numbers, passenger volumes, fleet size, alliance memberships, business model classifications (LCCs vs. full-service carriers), ownership structures (government or private), and participation in the UDAN scheme. It also considers exogenous factors such as the global financial crisis and the COVID-19 pandemic. By identifying factors influencing revenue generation and cost structures, the chapter aims to highlight financial inefficiencies and propose strategies to enhance the sector's resilience, aligning it with the demands of a rapidly expanding economy.

The COVID-19 pandemic severely disrupted global aviation, challenging the operational and economic resilience of airports. For Indian airports, particularly the busiest ones, these challenges highlighted the importance of operational and financial adaptability. Resilience studies in developed markets have extensively examined recovery mechanisms (Amirzadeh et al., 2023), but limited research has explored how Indian airports navigated and recovered from such disruptions. The second chapter in this thesis evaluates the resilience of India’s top 10 busiest airports by analysing passenger and cargo operations from 2016 to 2024 with a focus on the period starting in March 2020 due to the lockdown. Using advanced forecasting techniques (Rudakouski, 2023; Woźniak, 2016), the research investigates the divergence between predicted and actual performance patterns to identify factors that facilitated recovery.

These insights contribute to the broader understanding of airport resilience, offering valuable strategies for managing future crises. By identifying adaptable measures to enhance resilience, this chapter provides a roadmap for policymakers, airport stakeholders, and governmental agencies to respond effectively to future disruptions and expedite recovery.

To address structural challenges such as inadequate regional connectivity, underutilised airport infrastructure, and high travel costs, the Indian government introduced the National Civil Aviation Policy (NCAP) in 2016 (AAI, 2021). A key element of this policy is the UDAN scheme, designed to democratise air travel by expanding affordable regional connectivity (Iyer & Thomas, 2020). The scheme seeks to stimulate economic activity in underserved regions through fiscal incentives and infrastructure development. Despite its ambitious objectives, the UDAN scheme has faced significant impediments, including stakeholder conflicts, infrastructure limitations, and the compounded effects of the COVID-19 pandemic, which disrupted regional airport operations (Iyer & Thomas, 2020; Khan, 2023). Since 2008, the Indian government has taken a strategic approach with initiatives like the Greenfield Airports (GFA) policy (Mukherjee, 2023), which laid the groundwork for subsequent programs like UDAN by enhancing infrastructure and promoting regional connectivity. Therefore, the third chapter in this thesis examines these challenges from the perspectives of the identified stakeholders, offering insights into the socio-economic and operational complexities of the scheme's implementation. By identifying key gaps, this chapter seeks to provide actionable recommendations for enhancing the scheme's long-term impact and viability, addressing issues such as infrastructure deficits, bureaucratic hurdles and financial constraints.

Collectively, these three interrelated studies offer a comprehensive analysis of critical dimensions within India's aviation sector. The first Chapter investigates the financial sustainability of Indian airlines, while the second evaluates the resilience of airport-level market demand, measured through passenger and cargo volumes, in response to the disruptions caused by the COVID-19 pandemic. The third Chapter explores the challenges hindering the effective implementation of regional connectivity through the UDAN scheme. Together, these studies highlight how policy interventions like UDAN, evolving market demand, and unprecedented shocks such as the pandemic interact to shape the operational and structural complexities of the industry. As a founding member of the International Civil Aviation Organisation (ICAO) and a pivotal player in global aviation, India's approach to addressing these challenges will significantly influence the industry's future trajectory, underscoring the need for integrative and rigorous inquiry.

Research objectives

This PhD thesis acknowledges the ambitious strategic growth projections for Indian aviation, as envisioned by the government and the civil aviation authorities. Recognising the contemporary relevance and importance of Indian aviation, the research adopts a multidimensional approach to explore three critical aspects: airlines, airports and regional connectivity, particularly in the wake of the COVID-19 pandemic. Accordingly, the thesis addresses the following research objectives:

1. To contribute to a broader understanding of the Indian aviation sector's financial dynamics by examining airline operating expenditures and revenues, using robust analytical methods to address potential endogeneity.

2. To examine post-pandemic resilience patterns in India's aviation sector by analysing passenger and cargo recovery trends, using data from the country's top 10 busiest airports to identify factors contributing to deviations from forecasted performance.

3. To investigate sector-wide implementation and sustainability challenges in India's aviation industry by analysing stakeholder perspectives, using the UDAN scheme as an empirical case of regional connectivity policy.

This research integrates both empirical and qualitative methods to examine the interconnected challenges faced by the Indian aviation industry. By analysing Indian airlines, regional aviation, and airport resilience across the pre-pandemic, pandemic, and post-pandemic periods, this thesis provides a comprehensive perspective on the sector's performance, challenges, and adaptability in response to disruptions.

Contributions and managerial implications

This PhD thesis offers a comprehensive and multidimensional contribution to the understanding of India's aviation sector, with a particular focus on airline operations, regional connectivity, and airport resilience. It addresses some of the most pressing theoretical and practical questions facing the aviation industry in the post-pandemic era, especially within the context of a rapidly growing emerging market. By drawing together three interrelated strands—airline cost-revenue dynamics, airport infrastructure and operational resilience, and stakeholder perspectives on policy implementation—this research presents a cohesive body of work that extends academic knowledge and provides valuable insights for practice. Importantly, it situates these issues within a broader policy and economic framework, offering guidance to a wide range of aviation stakeholders including airlines, airport operators, regulators, and travel service providers. Taken as a whole, the thesis not only fills key research gaps but also contributes to the development of sustainable strategies for future growth and recovery in Indian aviation.

1. A major theoretical contribution of this thesis is its investigation into revenue generation in Indian airlines, with a specific focus on cost structures and the issue of endogeneity in operating expenditure. Previous studies have often failed to account for the complex interrelationships among input costs. This research highlights the number of aircraft in an airline's fleet as a key variable—both as a determinant of revenue and

as a strategic outcome shaped by market conditions. This dual role introduces a simultaneity problem, where fleet size is both influenced by and influences revenue performance and cost decisions. Such simultaneity can lead to estimation bias, which this study addresses through the application of robust econometric methods. By correcting for this bias, the study offers a more reliable understanding of airline financial performance, especially in an environment where profitability is under constant pressure due to regulatory constraints, price competition, and infrastructure limitations. For airlines, the findings present a clear rationale for more data-driven and strategically balanced decisions around fleet expansion and cost optimisation (see Chapter 1).

2. The thesis also contributes significantly to the growing literature on airport resilience by empirically assessing how India's major airports responded to the disruptions brought about by the COVID-19 pandemic. Using advanced quantitative techniques, including Bayesian vector autoregression (BVAR) and ordered logit (OLOGIT) modelling, the research explores non-linear recovery trajectories and identifies varying patterns of passenger and cargo traffic resilience across different airports. This methodological innovation allows for a more dynamic and forward-looking analysis of how airports adapt to exogenous shocks, something that traditional linear models might fail to capture adequately. From a managerial perspective, these findings suggest that while infrastructure robustness is fundamental, the variation in recovery patterns also points to the potential role of adaptive strategies such as flexible planning and proactive crisis management—areas worthy of further qualitative exploration. The research offers practical implications for policy makers, airport planners and operators looking to future-proof their facilities against disruptions ranging from health emergencies to climate-induced events (see Chapter 2).

3. Further, this thesis makes a unique contribution by offering the first detailed investigation of stakeholder perspectives on the implementation and future sustainability of the UDAN regional connectivity scheme in India. Unlike previous studies that have focused on operational metrics or policy outcomes in isolation, this research incorporates qualitative data gathered from a diverse group of stakeholders including airline representatives, airport managers, regulatory authorities, and travel agents. Their perspectives reveal the multilayered challenges that hinder the effectiveness of UDAN, including inconsistent funding mechanisms, misaligned infrastructure readiness, policy delays, and limited community engagement. The study demonstrates that achieving the goals of regional connectivity requires more than route subsidies; it calls for institutional coordination, long-term vision, and stakeholder buy-in. By capturing these nuanced views, the research provides a more grounded and realistic understanding of what it takes to deliver equitable and sustainable air access to underserved regions of the country (see Chapter 3).
4. The exploration of airline economics in Chapter 1 not only contributes to the theoretical understanding of cost structures and revenue performance but also provides an important contextual foundation for interpreting the commercial feasibility of regional routes, especially those supported under the UDAN scheme. Airlines operating in these markets often face higher operational costs and lower load factors, which make profitability contingent on factors such as optimal fleet utilisation, route selection, and cost efficiency. By uncovering the structural and strategic constraints inherent in airline operations, this chapter helps explain some of the reluctance or limitations faced by carriers in fully embracing regional connectivity initiatives. These insights directly support and enrich the stakeholder concerns raised in Chapter 3 regarding route viability and scheme sustainability, thus reinforcing the economic underpinnings of

policy implementation and highlighting the interdependence between microeconomic strategy and macroeconomic policy (see Chapters 1 and 3).

5. In a similar vein, building upon the challenges identified in Chapter 3 concerning the UDAN scheme, Chapter 2 builds on the discussion by focusing on the operational resilience of airports, which is crucial to the effective implementation of regional connectivity. While UDAN aims to boost regional access and enhance connectivity, its success is directly tied to how well airports can adapt to disruptions, as demonstrated during the COVID-19 pandemic. This continuity and adaptability are vital for the long-term sustainability of both the UDAN scheme and India's broader aviation infrastructure. The analysis of airport resilience in Chapter 2 complements the stakeholder perspectives outlined in Chapter 3, offering insights into how resilience strategies can mitigate risks and enhance the long-term success of regional connectivity initiatives (see Chapters 2 and 3).
6. Taken together, the three empirical studies presented in this thesis form a coherent and integrative body of work that deepens understanding of the financial, infrastructural, and policy-related dimensions of Indian aviation Chapter 1 articulates the financial realities and strategic adaptations of Indian airlines, Chapter 2 evaluates the capacity of major airports to recover from crises and maintain performance, and Chapter 3 brings in the perspectives of key stakeholders to assess the feasibility and future trajectory of a major national policy. By integrating these dimensions, the thesis provides a comprehensive analysis of the key factors influencing the growth and sustainability of Indian aviation in the post-pandemic context. It synthesizes theoretical perspectives on airline economics, empirical insights on airport resilience to present a holistic understanding of the sector, and practical challenges in regional connectivity. The strength of the thesis lies in its ability to weave these distinct but interrelated themes

into a unified narrative that reflects the complexity and dynamism of India's aviation landscape. This integrated approach not only advances theoretical knowledge but also offers practical value for stakeholders aiming to navigate the uncertainties and challenges of a post-pandemic world. Through the synthesis of multiple levels of analysis, the thesis contributes to more informed decision-making, supports better-targeted policy interventions, and aids the design of more resilient and inclusive aviation systems (see Chapters 1, 2, and 3).

A formatting note

This PhD thesis comprises three studies, with each study corresponding to a chapter. One study has been published, while the other two are being prepared for publication. It is important to note that editorial adjustments have been made to all studies, primarily related to formatting elements such as tables and figures. The thesis adheres to the APA 7th edition style for references. While the versions presented here have been published or are under review, no modifications have been made to the substantive content of the studies. Additionally, the term "chapter" refers to the entire chapter, including the preamble, whereas "study" specifically denotes the individual work that has been published or is currently under review. Some repetition may be present throughout the thesis; however, in accordance with the Massey University Graduate Research School's Doctoral Thesis with Publication Guidelines, this repetition is an inherent aspect of the thesis with publication pathway and cannot be avoided.

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Student name:	Ajai Jayathilakan
Name and title of main supervisor:	Dr Thanh Ngo — Senior Lecturer
In which chapter is the manuscript/published work?	Chapter 1

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The candidate contributed 80% to the manuscript/publication, undertaking the research, analysis, and manuscript preparation with notable independence and initiative. The supervisory team provided methodological guidance, helped refine the analysis, and offered critical feedback during the review process. The work is largely attributable to the candidate, with supervisory input focused on enhancing the quality of the final output.

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Chapter One – Indian aviation: Airlines

Preamble

The Indian aviation industry has witnessed remarkable growth over the past two decades, evolving into one of the world's most dynamic and rapidly expanding air travel markets. This transformation has been driven by a confluence of factors, including rising middle-class incomes, increasing urbanisation, supportive government policies, and the liberalisation of the aviation sector. A particularly influential development has been the emergence and consolidation of low-cost carriers (LCCs), which have disrupted traditional business models and made air travel more accessible to a broader segment of the population. Despite these advancements, the sector continues to grapple with persistent financial instability. Indian airlines operate in a highly price-sensitive environment marked by intense competition, fluctuating fuel costs, and infrastructure bottlenecks. These challenges have placed considerable pressure on airlines to balance operational efficiency with financial sustainability. As a result, understanding the determinants of airline revenue and identifying performance-enhancing strategies have become critical areas of inquiry, especially for carriers operating on narrow margins. This chapter introduces the broader landscape of Indian aviation and the specific economic and operational dynamics that shape airline performance. This chapter aims to contextualise the central research question of examining the determinants of Indian airlines' revenues within the framework of a competitive and often volatile market. It begins by mapping industry trends and historical developments, providing a foundation for understanding the dynamics of the sector. Next, a conceptual overview of key revenue-related variables is presented, which supports the subsequent econometric analysis. This analysis is designed to uncover meaningful patterns and relationships that can contribute to both academic knowledge and industry practices.

Study One: Examining the determinants of Indian airlines' revenues

Publication status and candidate contribution

This study was published in the *Journal of Air Transport Research Society (JATRS)* in August 2024, with the PhD candidate serving as the first and corresponding author, and the supervisors listed as co-authors. The PhD candidate was primarily responsible for the research, primary analysis, and writing of the first draft of this study. Throughout the process, the supervisory team provided invaluable support through critical feedback, academic guidance, and constructive suggestions, which were instrumental in refining and enhancing the quality and coherence of the final thesis.

1.0 Abstract

The Indian aviation sector has undergone remarkable growth, driven by the emergence of low-cost carriers and diverse business models, resulting in a surge in passenger numbers and aircraft orders, establishing India as a vibrant global aviation market. However, this rapid expansion is accompanied by significant financial challenges, leading to distress and insolvency among numerous airlines. Despite optimistic growth forecasts, high operating costs and relatively low revenue returns pose substantial hurdles. Motivated by these challenges, this study aims to uncover the key factors influencing revenue generation in the Indian aviation industry by analysing expenditure components and their impacts on costs. The objective of this study is to address the research gap stemming from the lack of previous studies on Indian airlines that address endogeneity issues related to airline expenditures. By utilising data from 2007 to 2022 sourced from the audited annual reports of each airline, we aim to provide essential insights into the revenue dynamics of Indian airlines through the application of various econometric models including IV regression and GMM models for improving causality and addressing

endogeneity. Our findings reveal a positive correlation between unit revenue and factors such as unit expenditure (UEXP), staff numbers (STAFF), and passenger volume (PAX), while also highlighting the positive impacts of airline alliances (Alliance) and regional connectivity schemes (UDAN). This research not only sheds light on industry intricacies but also underscores the imperative to address key variables to enhance the sector's sustainability and resilience in the face of ongoing challenges, offering valuable contributions to both academia and industry stakeholders for informed decision-making and strategic planning.

1.1 Introduction

The worldwide aviation sector is grappling with significant challenges from various factors, especially the recent COVID-19 pandemic (e.g., Agrawal, 2021; Gandhi & Gandhi, 2020; Jha et al., 2021; Nhamo et al., 2020; Shroff, 2020; Sidhu & Shukla, 2021; Sobieralski, 2020; Sun et al., 2022a). This has led to a phase of economic hardship and decreased productivity, especially in terms of financial self-reliance. Balancing cost reduction with revenue enhancement is a major global challenge for airlines. Additionally, managing passenger preferences, aircraft performance, fuel costs, competition, and unforeseen variables complicates the situation further (e.g., KİRACI & Yaşar, 2020; Mahtani & Garg, 2020; O'Connell et al., 2013; Sun et al., 2024).

India, with its 1.4 billion population and diverse airline business models, is one of the world's most challenging aviation markets. Issues such as rising fuel prices, overcapacity, intense price competition, and prolonged protectionism of Air India exacerbate these challenges (Asquith, 2019; Saranga & Nagpal, 2016). Despite a rise in passenger numbers, increasing disposable incomes, and government policies promoting foreign direct investment (FDI) in aviation (e.g., Chandrachud et al., 2019; Choudhuri et al., 2013; Vipin, 2012), the entry of new airlines and the impact of COVID-19 pandemic have intensified pressures, leading to financial strains and some companies facing bankruptcy (Sharma & Gupta, 2019; Shome & Verma, 2020).

However, the Indian aviation sector has shown impressive growth, especially before the pandemic. Since 2004, the industry has expanded remarkably due to transformative Civil Aviation Policies and government interventions. O'Connell et al. (2013) note that a substantial and growing middle class, favourable demographics, rapid economic progress, and higher disposable incomes have driven this growth. This study primarily investigates how airline operational metrics and external factors influence the revenue of six participating airlines, including low-cost, regional, and full-service carriers. Additionally, it addresses a gap in existing research: to our knowledge, no previous studies have examined the endogeneity of operating expenditure in the context of Indian airlines while evaluating their revenue.

The financial struggles and the inability of Indian airlines to weather such challenges, prompt the specific research question: *What are the determinants of Indian airlines' revenue?*

This question is particularly significant amid the challenges brought on by the COVID-19 crisis.

The subsequent sections of this study are organised as follows. Section 1.2 provides an overview of the Indian aviation sector, encompassing its historical evolution and current challenges. Section 1.3 provides an examination of relevant literature. The methodology, variables of interest, and data are presented in Section 1.4. Subsequently, Section 1.5 presents and discusses the empirical results, policy implications and recommendations. Section 1.6 then concludes the paper.

1.2 The Indian aviation industry

1.2.1 Historical development

The Indian aviation sector has a rich history, marked by significant milestones and rapid growth. The journey began in 1911 with the first commercial flight between Allahabad and Naini (both cities in Uttar Pradesh, India). In 1932, JRD Tata established Tata Air Services, initiating India's airmail service with a flight from Karachi to Mumbai (Hindu, 2021). Post-independence, TATA Airlines lost its majority stake, leading to the nationalisation of Air India by the Indian government in 1953 (Misra, 2021), resulted in the formation of Indian Airlines and Air India under government control, ensuring a more organised aviation sector. Over time, Air India transitioned from a prestigious national carrier to a financially troubled entity, necessitating the creation of two distinct airlines: Air India for international routes and Indian Airlines for domestic services, which eventually merged in 2007 (K. Wang et al., 2018). This merger sparked a wave of consolidations in the airline industry, such as Jet Airways acquiring Air Sahara and rebranding it as JetLite in 2007, and Kingfisher Airlines taking over Deccan in 2008 (Yu et al., 2019).

The deregulation of the aviation sector through initiatives like the 1986 Air Taxi Scheme and the Air Corporations Act in the 2000s facilitated the entry of new players such as East-West Airlines, Jet Airways, Damania Airways, and ModiLuft Airlines (Findlay & Goldstein, 2004). Kingfisher Airlines succumbed to financial woes post-2012, exacerbated by its merger with Air Deccan (e.g., Debnath et al., 2020; Panigrahi et al., 2019; Sharma & Gupta, 2019). Jet Airways, once a dominant player, filed for bankruptcy in 2019, unable to withstand competition from LCCs like SpiceJet and IndiGo (J. Ahmed et al., 2020). Although Jet Airways and Kingfisher Airlines were renowned for their premium services, they struggled to compete against rivals offering better value for money (Arushi & Drews, 2011). The key milestones of the Indian aviation industry are presented in Table 1.1 below.

Table 1. 1

Evolution of the Indian aviation industry

Year	Major milestones
1932	JRD Tata founded Tata Airline.
1948	The Indian government established Air India International Limited in collaboration with Tata Airline (as a joint stock

	company), leading to the first flight on the Mumbai-London air route.
1953	Nine airlines existed, including Air India and Indian Airlines.
1953	Nationalisation of all private airlines through the Air Corporations Act.
1986	Private carriers are permitted to operate as air taxi operators.
1994	Air Corporation Act was repealed; Private carriers were allowed to operate scheduled flight services.
1995	Jet Airways, Air Sahara, Modiluft Airlines, Damania Airways, and East-West Airlines were granted their scheduled carrier status.
1997	4 out of 6 carriers shut down; Jet Airways and Air Sahara continued to operate.
2001	Aviation turbine fuel (ATF) prices are decontrolled.
2003	Air Deccan started operations as India's first LCC.
2004	Air India Express started operations.
2005	Kingfisher, SpiceJet, IndiGo, GoAir, and Paramount Airways started operations.
2007	Indian airline industry consolidated; Jet Airways acquired Air Sahara; Kingfisher acquired Air Deccan.
2010	SpiceJet started international flight operations
2011	IndiGo started international flight operations; Kingfisher exited the LCC segment. The merger between Air India and Indian Airlines was completed.
2012	The Indian Government allowed direct ATF imports, FDI proposal for allowing foreign carriers to pick up to a 49 per cent stake of Indian carriers under consideration. Kingfisher bankrupted.
2014	Falling international crude prices led to sharp cuts in the price of ATF. Debt-ridden SpiceJet cancelled flight services, cut a third of its aircraft fleet and sought help from the Indian government.

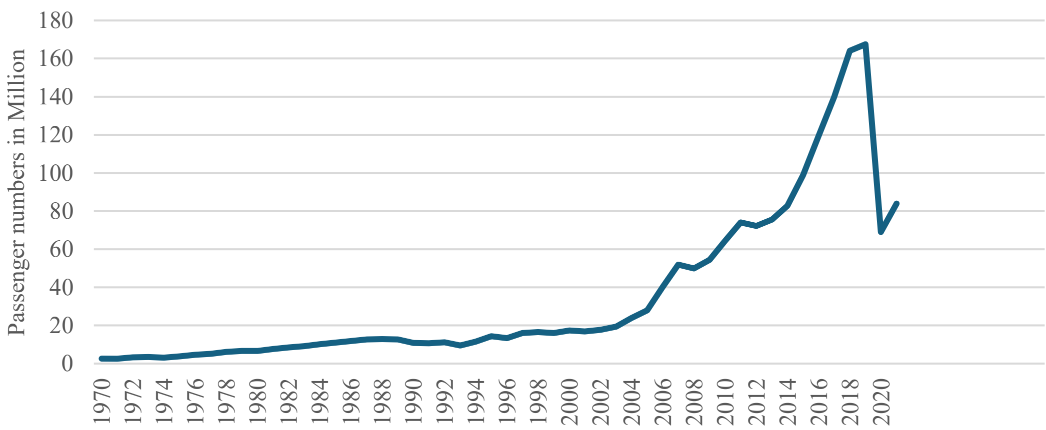
2019	Jet Airways ceased flight operations.
2022	Acquisition of debt-ridden national flag carrier Air India by TATA group.

Source: Jain & Natarajan (2015), DGCA (2021)

The steady increase in passenger numbers for Indian airlines since 1970 highlights the significant growth of the Indian aviation industry (see Figure 1.1), particularly from 2004 onward due to the rise of low-cost carriers. This development has played a crucial role in shaping the aviation sector and has greatly contributed to the flourishing tourism industry.

Figure 1. 1

Passenger growth of Indian airlines (1970−2020)



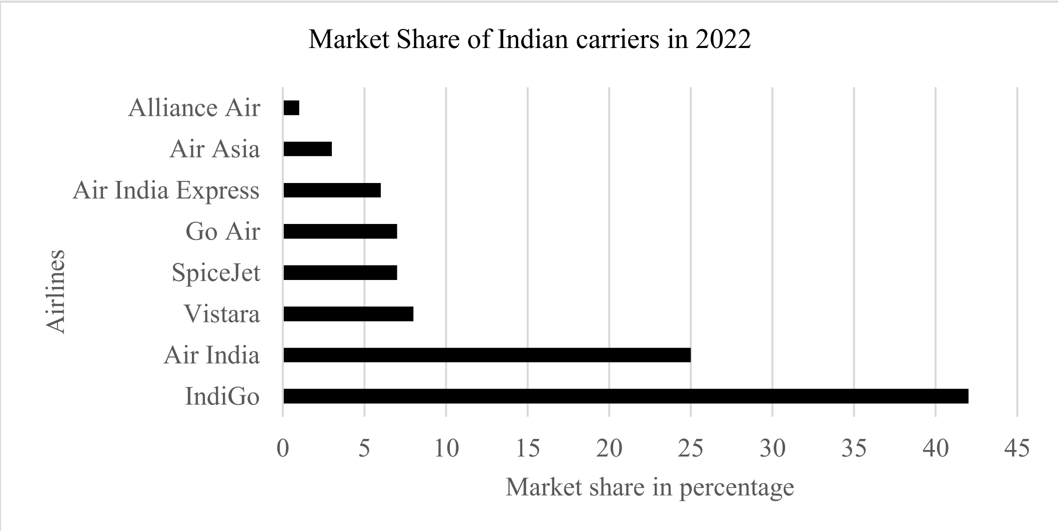
Source: Worldbank (2021)

1.2.2 Current issues facing the Indian aviation industry

The liberalisation policies of the 1990s transformed the Indian aviation industry, opening skies to private players and low-cost carriers. This led to a surge in passenger volumes, driven by LCCs and government initiatives for infrastructure upgrades and improved connectivity. Despite these favourable conditions, the industry faces challenges like high fuel prices, operational inefficiencies, and stiff competition (Yadav, 2020). O’Connell et al. (2013) noted that bureaucratic policies and state monopolisation historically hindered India's aviation sector. Reforms, including 1990s trade liberalisation and the Naresh Chandra Committee in 2002, aimed to improve air transport services and the competitiveness of state-owned airlines (Ray, 2014). Saranga & Nagpal (2016) highlighted that post-2010 fuel prices in India were 50% higher than in West Asia and Europe, exacerbating overcapacity, intense price competition, and the global financial crisis (GFC). These factors led to ongoing losses, culminating in Kingfisher Airlines' shutdown in 2012. Figure 1.2 illustrates the market share of Indian carriers for the year 2022. IndiGo leads with the largest market share in the domestic aviation market, followed by other airlines. The disparity in market share among the carriers is quite prominent.

Figure 1. 2

Market share of Indian airlines in 2022



Source: DGCA (2022)

Sakthidharan and Sivaraman (2018) observed that Air India had the highest inefficiency in managing non-fuel operating costs, becoming a significant state liability. In October 2020, Civil Aviation Minister Hardeep Singh Puri announced bids for Air India would be accepted based on enterprise value, aiming to optimise operations and reduce costs (Misra, 2021; Mohan, 2021). Air India's disinvestment sought to reduce the government's daily loss of Rs 20 crore (USD 2.7 million), amounting to an annual loss of Rs 7,300 crore (USD 986 million) (Misra, 2021). Challenges persist, such as a shortage of maintenance, repair, and overhaul (MRO) centres, leading to financial losses (IANS, 2021). Ahmed and Ahmed (2020), stated that airlines like Jet Airways continue to struggle financially amid competition and rising operational costs. As illustrated in Figures 1.3A and 1.3B, which present the financial performance of Indian full-service carriers (FSCs) and low-cost carriers (LCCs) from 2007 to 2019, Indian airlines consistently struggled to align revenues with operating expenditures, a challenge further intensified by growing LCC competition and persistent price wars (e.g., Agrawal, 2021; Jain & Natarajan, 2015; O'Connell et al., 2013; Sakthidharan & Sivaraman, 2018; Saranga & Nagpal, 2016; Singh et al., 2019; Wang et al., 2018).

Figure 1. 3A

Financial performance of the Indian full-service carriers (2007−2019)

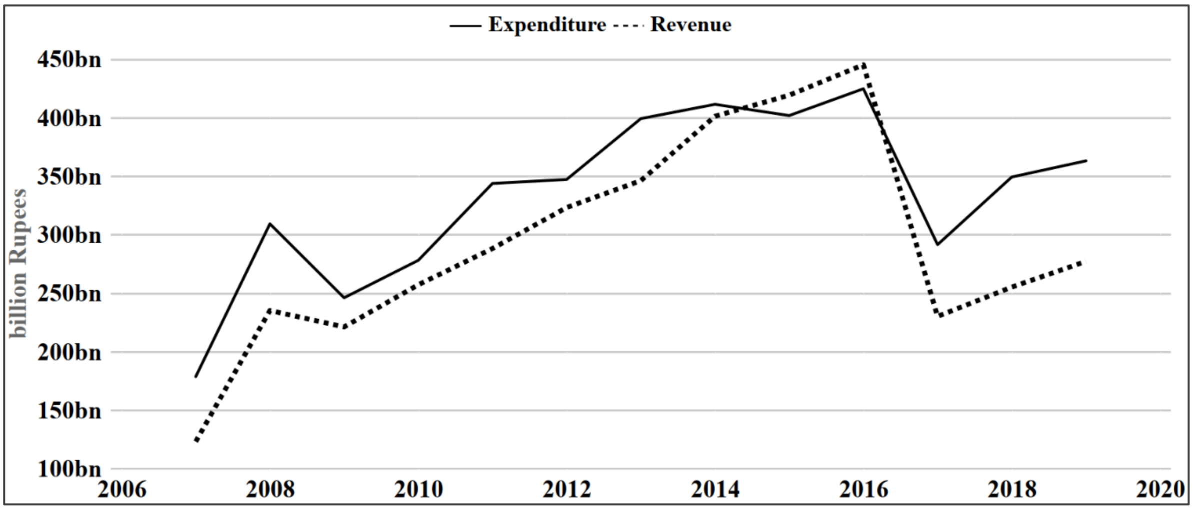
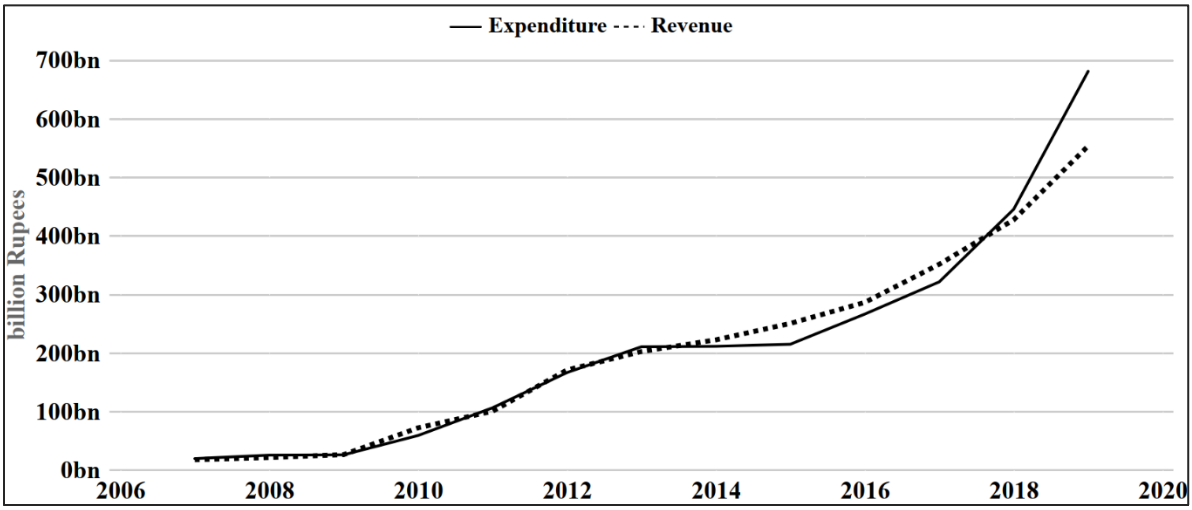


Figure 1. 3B

Financial performance of the Indian low cost carriers (2007−2019)



Source: Author's calculations from annual reports of Air India, Indigo, Jet Airways, Spice Jet, Air India Express, and Alliance Air.

Concurrently, the unpredictable fluctuations in global fuel prices posed a persistent financial risk, further complicating the financial stability of airlines. This necessitated prioritising operational efficiency and adaptability to navigate the aviation industry's complexities. The Indian government has been proactive in launching aviation-related initiatives that have evolved into policies aimed at nurturing the sector. Key initiatives include RCS, infrastructure investments, and regulatory reforms. The UDAN scheme enhances regional connectivity by making air travel affordable and operationalising underserved airports through subsidies and financial incentives to airlines (Das et al., 2020; Iyer & Thomas, 2020). Infrastructure investments aimed at expanding and modernising airports, with significant projects involving new airports and upgrading existing ones. Additionally, regulatory reforms have eased the operational environment for airlines, including simplifying new route approvals and reducing aviation fuel taxes. The National Civil Aviation Policy (NCAP) contributed by reducing aviation turbine fuel (ATF) taxes and removing FDI restrictions (MoCA, 2019a). A notable milestone was the abolition of the 5/20 rule in 2016, allowing airlines to operate internationally without extensive domestic experience (Chandra, 2018). Amid prolonged financial difficulties, Air India, struggling financially, was taken over by the Tata Group in 2022, marking a significant development in Indian aviation.

Among various challenges, the COVID-19 pandemic had been the most impactful. Dube (2022) cited India as the source of the highly contagious Delta variant, exacerbating the situation. Sun et al. (2022b) highlighted the pandemic's profound impact on aviation, causing irregular flight bans and complicating assessments of aviation stakeholders. Jackson et al. (2021) identified India and Brazil as viral hotspots by April 2021, leading to stringent restrictions on airlines. Grounded flights caused a steep decline in passenger traffic, resulting in substantial revenue losses estimated at up to US$113 billion (Mohapatra et al., 2021).

Despite achieving a robust Compound Annual Growth Rate (CAGR) of 14.5% in domestic passenger traffic from 2014-15 to 2019-20 (MoCA, 2023), the industry saw a sharp downturn due to the pandemic. Dube et al. (2021) underscored the severity, noting significant revenue losses for individual airports, impacting the financial stability of both airports and air navigation companies.

The Indian aviation sector stands at a unique juncture, characterised by rapid growth driven by a burgeoning middle class and increasing urbanisation. While global aviation focuses on technological advancements and sustainability, India faces challenges like infrastructure constraints and a complex regulatory environment. Nath and Upadhyay (2024) highlight bureaucratic red tape, outdated infrastructure, and inefficient customs procedures at Indian air cargo terminals. They suggest streamlining customs, adopting artificial intelligence (AI), upgrading infrastructure, and coordinated stakeholder efforts to enhance efficiency and competitiveness. Cost sensitivity among Indian consumers shapes airline strategies, favouring low-cost carriers that dominate the market. Wang et al. (2014) suggest that airport concentration in India could yield cost efficiencies, potentially reducing airfares. Supported by favourable policies, initiatives like UDAN aim to strengthen regional connectivity, integrating remote areas into the economic mainstream.

The inclusion of new startup carriers, such as the launch of Akasa Air in 2021, underscores these efforts in shaping Indian aviation. Molewijk (2023) posits that startups foster innovation, risk-taking, and strategic collaborations with established organisations. PTI (2024) forecasts that Indian airlines will achieve a 50 percent market share in international passenger traffic by FY 2027−2028, presenting opportunities for new startups. Sun et al. (2022a) observed that the pandemic created a unique environment for airline startups, characterised by significant challenges and opportunities. Technological leapfrogging is evident with India embracing digitalisation and sustainable aviation fuels to address environmental impacts, while developing skilled manpower remains a priority amidst global shortages.

1.3 Literature review

1.3.1 Airline revenue and its determinants

Most studies consider revenue a key indicator of financial performance, which is strongly influenced by the airline's expenditure or costs (Barnhart et al., 2009; Dunleavy & Phillips, 2009).

Oum and Yu (1998) conducted a comprehensive analysis of the cost competitiveness of 22 major airlines from 1986 to 1993. They employed a translog variable cost function to break down unit cost differentials into input prices, network and output attributes, and efficiency. This detailed decomposition, along with the innovative use of a multilateral index procedure, highlights the study's methodological strengths. Their key findings indicate that Asian carriers (excluding Japanese) exhibited higher cost competitiveness compared to their U.S. and European counterparts. Despite potential data inconsistencies and assumptions about capital input equilibrium, the study significantly enhanced understanding of cost drivers in the airline industry and provided insights for policymakers and management, aligning with findings that higher unit expenditure can boost revenue. Future research should broaden the range of airlines, include recent data, and offer detailed regional analyses.

An extensive analysis of prominent airlines by Windle (1991), used total factor productivity (TFP) to examine their response to post-deregulation dynamics. The study found that deregulation compelled airlines to enhance productivity, leading to cost reductions, with employee expenditure being a key variable. The strength of TFP lies in its holistic approach, considering multiple inputs—labour, fuel, flight equipment, ground property and equipment (GPE), and materials—which provides a thorough understanding of productivity changes.

However, reliance on the translog multilateral index procedure may introduce complexity and potential inaccuracies in measurement, which could affect the reliability of the findings. Despite this, the study's robust input selection and comprehensive analysis offer valuable insights into how even less efficient airlines managed to increase productivity by lowering prices and improving customer services in response to deregulation challenges. The detailed focus on key variables strengthens the study's conclusions, although potential methodological limitations should be considered when interpreting the results. Notably, the study highlighted that airline with lower efficiency during that period succeeded in augmenting their productivity by lowering prices and enhancing customer services in response to these challenges.

Merkert and Hensher (2011) employed a two-stage Data Envelopment Analysis (DEA) to evaluate airline efficiency, focusing on factors such as airline size, fleet composition, and aircraft variety to manage costs. This comprehensive approach assesses technical, allocative, and cost efficiency, providing nuanced insights into performance. The use of an input-oriented function highlights airlines' control over inputs, acknowledging external economic and contractual influences on outputs. Despite DEA's limitations, such as sensitivity to input/output selection and relative efficiency scores, the study’s robust findings reveal that fleet age does not significantly impact technical efficiency but positively affects allocative and cost efficiency. Higher fuel costs, as noted, can drive up consumer prices and increase airline revenue, supported by Sibdari et al. (2018). As these findings have significant implications for airline management, Camilleri (2018) also highlights profitability factors like sector length, aircraft utilisation, fleet size, and labour costs, with corroborating results found by Chang and Shao (2011), Bitzan and Peoples (2016), and O’Connell et al. (2020).

Sibdari et al. (2018) examined endogeneity in airline expenditure, focusing on how passenger demand, cost per gallon, and unemployment rate affect capacity decisions, including flight frequency, aircraft size, and load factor. The study spotlights on significant correlations between these factors and operational adjustments. Recognising bidirectional causality is crucial, as airlines' strategic decisions can influence economic conditions like fuel costs and unemployment rates, adding complexity to causality attribution. Addressing endogeneity not only strengthens empirical findings but also sheds light on how airlines adapt to diverse economic environments.

In summary, airline financial performance is closely linked to expenditure, yet much of the existing literature overlooks the potential endogeneity arising from underlying operational factors that simultaneously influence both variables. In particular, expenditure is endogenous because it is shaped by structural characteristics such as the number of aircraft, which evolve in response to broader market conditions rather than short-term revenue changes. If this endogeneity is ignored, estimates of the expenditure–revenue relationship may be biased and lead to misleading conclusions.

To address this issue, the present study uses the number of aircraft as an instrument for expenditure. The number of aircraft affects operating costs but is plausibly exogenous to short-term revenue fluctuations, enabling correction for endogeneity and allowing more reliable estimation of the relationship between expenditure and financial performance. This approach aligns with prior work emphasising the need to appropriately instrument endogenous expenditure in airline performance studies.

1.3.2 Efficiency and performance of Indian airlines

Research on Indian airlines, particularly in terms of expenditure and revenue, has been a subject of growing interest in recent years. Jain and Natarajan (2015) found that the influx of LCCs, including government-backed Air India Express and private LCCs like GoAir, IndiGo, and SpiceJet, improved competitiveness in the Indian market, emphasising the significance of ownership. This study utilised DEA and noted that aggressive capacity expansion and inability to control costs led to mounting losses, impacting revenue and potentially causing bankruptcy or acquisition. Similarly, O'Connell et al. (2013) stated that the issues on restrictions on foreign ownership, the outdated regulatory policies, over taxed fuel and the industry-wide overcapacity were the major contributing factors towards ailing aviation scenario in India.

Saranga and Nagpal (2016) analysed the determinants influencing the market performance of the Indian airline industry from 2005 to 2012. Using a two-way random effects GLS regression and Tobit model, they uncovered those structural and regulatory factors negatively impacted performance, while operational efficiencies within the low-cost segment were notable. Their findings highlighted that technical efficiency, particularly through enhanced pricing power, played a pivotal role in improving market performance and revenue. The study also revealed that load factor, representing the ratio of revenue passenger kilometer (RPK) to available seat kilometer (ASK), positively impacted operational efficiencies. Furthermore, the choice of aircraft fleet operated by Indian airlines was found to be a pertinent factor. While the methods used addressed unobserved heterogeneity and censored data, their complexity may challenge interpretation for non-specialists.

A comparative study of Indian airlines by Wang et al. (2018) stated that Air India's performance could be deteriorating because of two essential aspects: competition from other private airlines and LCCs. Their study employed log-linear demand and supply equations to model pricing dynamics and passenger demand within the airline industry. They found that the presence of an operating LCC on specific routes reduced costs, lowered airfares, and boosted demand for air travel in India. The study also indicated that high airport concentration in India could enhance passenger travel and connectivity. Despite methodological strengths, such as modelling pricing dynamics and demand, the log-linear approach's assumptions about constant elasticities of demand may overlook nonlinear consumer responses. Ganesh (2011) observed that pilots accounted for around 34% of the total manpower costs for scheduled Indian carriers during the 2008-2009 period, despite constituting only 7% of the workforce. This high expense could be linked to additional costs associated with introducing new aircraft, leading to potential shortages of trained instructors and related training expenses.

A panel data analysis by Singh et al. (2019) examined the impacts of different factors on the operational expenditure of Indian airlines. Key variables included available seats per kilometer, payload, average fuel price, flight duration, and ownership. Their multiple regression analysis revealed that operating larger aircraft and increasing payload significantly improved cost efficiency, reducing expenses per Revenue Passenger Kilometer (RPK). They suggested mergers and code-sharing arrangements as potential strategies to enhance efficiency from an Indian perspective. Additionally, the study identified aviation fuel costs as the most crucial factor contributing to rising operational expenditures. The chosen methodology effectively controls for unobserved heterogeneity across different airlines and over time, enhancing the robustness and reliability of the findings.

Similarly, Mahtani and Garg (2020) applied a logistic regression model to analyse Indian airline data from 2006 to 2017, covering seven prominent airlines. They confirmed that fluctuations in fuel prices influenced revenue and profits, impacting key variables such as load factor, fleet size, operating revenues per revenue passenger kilometer (RPKM), operating expenses per RPKM, labour costs, and various financial ratios. The logistic regression model is suitable for examining the impact of multiple factors on discrete outcomes like profitability. However, it assumes a linear relationship between the log-odds of the dependent and independent variables, which may not fully capture complex data interactions, necessitating careful variable specification and addressing issues like multicollinearity to ensure accurate results.

Sakthidharan and Sivaraman (2018) examined major domestic carriers in India using DEA, finding their technical efficiency ranged from 71% to 89% for the period of 2013−2014. DEA inputs included revenue passenger kilometer (RPKM) and freight tonne kilometer (FTKM), while outputs covered available tonne kilometer (ATKM), cost per available seat kilometer, fuel costs (with and without) per ASK, maintenance costs per ASK, ownership costs per ASK, and the number of employees. Their analysis indicated that LCC models contribute to cost reduction by maintaining a younger fleet, particularly in terms of maintenance.

An exception is a recent study by Shome and Verma (2020) using bankruptcy prediction models to examine the financial performance of Indian airlines. Their results showed that the Indian airline industry was problematic with one airline facing bankruptcy every five years. It triggered us to further examine the financial performance, i.e., revenues, of Indian airlines more carefully.

1.3.3 Impact of external factors

In light of decreasing profit margins, Garg and Agrawal (2023) utilised a fuzzy-based AHP framework to assess key performance indicators (KPIs) of Indian airlines. Their analysis highlighted safety and security as primary focus areas, followed by operational, marketing, customer relations, and financial factors. This model offers a method for evaluating KPIs crucial for Indian airlines.

Using a multi-criteria decision-making (MCDM) approach, Mahtani and Garg (2018) found that LCCs generally exhibited higher efficiency in ownership structures, while government carriers benefited from privileges, aligning with global trends. Key factors included fuel prices, inflation, GDP growth, and passenger traffic. Das et al. (2020) cited political influence through government ownership as significant, suggesting state-owned airlines balance commercial and social obligations amid competition from efficient LCCs.

Sidhu and Shukla (2021) conducted a comprehensive analysis of airline parameters from 2019 and 2020, using a correlation matrix to assess significant impacts on the Indian aviation industry. Their study focused on metrics such as passenger load factor (PLF) and revenue performance, revealing the severe effects of COVID-19 on industry volatility and preparedness. Unlike studies limited to single airlines, this research examined the pandemic's effects on the entire industry, offering insights into flight performance and financial endurance. They emphasised the need for robust sustainability protocols to ensure airline survival in unpredictable scenarios, as supported by Dube et al. (2021), Nhamo et al. (2020) and Sun et al. (2023). Furthermore, Barik et al. (2021) observed a significant decline in stock prices of Indian airline companies immediately following the first reported COVID-19 case.

The literature review underscores a complex interplay between operational efficiency, market performance, and external factors in shaping airline revenue. Effective cost management, particularly concerning labour and fuel costs, strategic operational adjustments, and efficient fleet management are critical for revenue enhancement. Additionally, market conditions, regulatory policies, and economic factors significantly influence revenue outcomes. Addressing endogeneity and examining these relationships across varied economic scenarios, including crises like the global financial crisis (GFC) and COVID-19 pandemic, is vital for understanding revenue determinants in the Indian aviation context. Despite valuable insights from existing studies, gaps remain in addressing internal biases, such as endogeneity in expenditure determinants and the impacts of initiatives like RCS on operational costs, particularly regarding fleet size optimisation. Existing research often lacks comprehensive evaluations across different economic scenarios and detailed financial analyses during significant crises. This study aims to bridge these gaps, enhancing the understanding of Indian airlines' operational efficiency and financial resilience. Future research should focus on filling these methodological gaps to support effective management strategies within India's aviation industry.

1.4 Methodology

1.4.1 Empirical models

In this study on the revenue dynamics of Indian airlines, endogeneity issues were observed due to the expenditure variable, which is significantly influenced by the number of aircraft. To address this, instrumental variables (IV) regression and generalised method of moments (GMM) estimation were employed. IV regression helps mitigate endogeneity by using instruments correlated with expenditure but uncorrelated with the error term, ensuring unbiased and consistent estimates. GMM extends this approach, offering a flexible and efficient framework, particularly useful for handling multiple endogenous variables and accommodating heteroskedasticity and autocorrelation in panel data (Ngo et al., 2022; Ullah et al., 2018). By leveraging these econometric methods, the aim is to obtain robust and reliable results, isolating the true impact of expenditure on airline revenue and enhancing the credibility of the findings. This methodological approach is essential for deriving meaningful insights and informing strategic decisions in the aviation industry. As previously mentioned, the objective of this study is to address the research gap stemming from the lack of previous studies on Indian airlines that address endogeneity issues related to airline expenditures.

This methodological attention to endogeneity is critical because, in the Indian context, airlines operate in a highly price-sensitive and competitive market where expenditure decisions, particularly those related to fleet expansion, respond to demand and revenue expectations. This feedback makes expenditure endogenous to performance outcomes. In particular, factors such as the number of aircraft drive this endogeneity, and ignoring these biases can lead to inaccurate conclusions about how expenditure relates to performance.

While econometric results can provide valuable insights into causal relationships, ignoring endogeneity can produce biased estimations and limit research applicability (e.g., Gretz &

Malshe, 2019; Maung et al., 2022; Saranga & Nagpal, 2016; Ullah et al., 2018). This study utilised both fixed effects (FE) and random effects (RE) IV regressions to further enhance the robustness of the findings.

The number of aircraft in an airline's fleet is an endogenous factor in airline expenditure because it is influenced by both the demand for air travel and the airline's profitability, creating a feedback loop (e.g., Pitfield et al., 2010; Sibdari et al., 2018; Vasigh & Azadian, 2022). When airlines experience high demand, they may increase their flight capacity to capture additional sales, leading to higher profits. These increased profits enable airlines to expand their fleets, thereby offering more flights, creating a bidirectional effect. Thus, the fleet size is both a result of and a factor in the airline's financial performance and operational decisions.

The dependent variable of this study is the financial performance, i.e., revenue, of Indian airlines. To account for the differences across the airlines due to their sizes and scope of operations, instead of using total revenue, we employ the unit revenue (*UREV*, defined as total revenues divided by total stage length) as a 'fair' measure of the financial performance of the airlines. Regarding the determinants of revenue, as discussed earlier, our main focus is the airline's expenditure – similarly proxied by unit expenditure (*UEXP*). However, *UEXP* needs to be instrumented by the number of aircraft (*AC*), among other IVs, to account for potential endogeneity bias. As discussed in Section 1.3.1 above, *AC* significantly affects the airline's expenditure, and expenditure influences revenue (e.g., Camilleri, 2018b; Merkert & Hensher, 2011; Sibdari et al., 2018). The two-stage approach of Tsui (2017) and Ngo et al., (2022), among others, is applied to account for this endogeneity issue.

Theoretically, the positive correlation between *UEXP* and *UREV* observed in the Indian airline industry can be justified through the concept of cost-quality trade-offs. Increased expenditure on modernising fleet, expanding seating capacity, and improving operational efficiency allows airlines to provide better services, which in turn attracts more passengers willing to pay higher fares. This aligns with findings from Wojahn (2012) and Alamdari & Morrell (1997) suggesting that strategic investments in operational enhancements and service improvements are key drivers of revenue growth in the inherently cyclical airline industry.

Specifically, in the first stage, *UEXP* is regressed against *AC* and other exogenous variables using Equation (1.1):

$$UEXP_{it} = \alpha_0 + \alpha_1 AC_{it} + \alpha_2 PAX_{it} + \alpha_3 STAFF_{it} + \alpha_4 ALLIANCE_{it} + \alpha_5 LCC_{it} + \alpha_6 GFC_t + \alpha_7 COVID_t + \alpha_8 OWNERSHIP_{it} + \alpha_9 UDANRCS_{it} + \varepsilon_{it} \quad (1.1)$$

where *i* and *t* denote the airline and year, respectively.

Then, in the second stage of Equation (1.2), the predicted value of *UEXP* (accounted for *AC* already) is used as the key independent variable of *UREV*. Including lagged variables in a model helps address autocorrelation and omitted variable bias by incorporating the effects of past periods into the current period's analysis (Ullah et al., 2018). This helps to mitigate autocorrelation by accounting for the influence of previous observations on current observations, thus capturing temporal dependencies. Additionally, it reduces omitted variable bias by considering past information that could affect current outcomes, leading to more accurate and unbiased estimates of the model's coefficients.

Hence, the 1-year lagged value of *UREV* is included to account for other potentially omitted variables – this is a popular practice of GMM (see Roodman, 2009; Ullah et al., 2018) :

$$UREV_{it} = \gamma_0 + \gamma_1 UREV_{it-1} + \gamma_2 \widehat{UEXP}_{it} + \gamma_3 PAX_{it} + \gamma_4 STAFF_{it} + \gamma_5 ALLIANCE_{it} + \gamma_6 LCC_{it} + \gamma_7 GFC_t + \gamma_8 COVID_t + \gamma_9 OWNERSHIP_{it} + \gamma_{10} UDANRCS_{it} + \mu_{it} \quad (1.2)$$

The selection of the variables closely follows the literature, as outlined in Table 1.2.

Table 1. 2

Variable definitions and their expected relationship with airline revenue

Variables	Definitions	Expected Relationship	References
Unit Revenue ***UREV***	The ratio between operating revenue and stage length of airline *i* at year *t*	-	Singh et al. (2019)
Unit Expenditure ***UEXP***	The ratio between operating expenditure and stage length of airline *i* at year *t*	A positive correlation between expenditure and revenue exists, as increased spending often leads to higher earnings.	Singh et al. (2019)
No. of Staff ***STAFF***	The total staff of airline *i* at year *t*	More staff tends to reduce revenues	Singh et al. (2021)
No. of passengers ***PAX***	The number of passengers carried by airline *i* at year *t*	Expected to reduce expenditure and improve revenues	Kiraci and Yaşar (2020); Shao and Sun (2016); Singh et al. (2019)
No. of aircraft ***AC***	The total number of aircraft of each airline *i* at year *t*	Expected to improve revenue	Pitfield et al. (2010); Sibdari et al. (2018)
Member of any airline alliance ***ALLIANCE***	This binary variable takes the value of 1 when airline *i* joined alliance membership at year *t*, 0 otherwise	Tends to have a positive impact on airlines from both expenditure and revenues	Barros and Peypoch (2009); Yu et al. (2017)
Global financial crisis time period ***GFC***	This binary variable takes the value of 1 during the global financial crisis (2008 and 2009), 0 otherwise.	GFC has a negative impact on both expenditure and revenues	Merkert and Hensher (2011)

Low-cost carrier business model ***LCC***	This binary variable takes the value of 1 when airline *i* is a low-cost carrier at year *t*, 0 otherwise	LCCs are better in cost management and may be better in revenue generation	Wang et al. (2018); Saranga and Nagpal (2016)
COVID-19 pandemic time period ***COVID***	This binary variable takes the value of 1 during COVID-19 pandemic (2022), 0 otherwise;	COVID has a negative impact on both expenditure and revenue	Dube (2022); Maung et al. (2022); Sidhu and Shukla, (2021); Sun et al. (2023)
Ownership of the airline (government or private) ***OWNERSHIP***	This binary variable takes the value of 1 when airline *i* at year *t* is state owned, 0 otherwise	Non-governmental airlines tend to perform better in terms of expenditure and revenues	Singh et al. (2019); Wang et al. (2018)
Participant in ***RCS-UDAN*** ***UDANRCS***	This binary variable takes the value of 1 when airline *i* is member of UDAN scheme at year *t*, 0 otherwise	Regional connectivity schemes tend to have a positive impact in revenue	Iyer and Thomas (2020)

1.4.2 Data

The data for this study has been meticulously sourced from the Directorate General of Civil Aviation (DGCA) India and the annual reports of each airline. Airlines include Air India, Air India Express, IndiGo, SpiceJet, Alliance Air and Jet Airways (Jet Airways suspended operation since 2019). By obtaining data directly from these authoritative sources, the highest level of accuracy and reliability is ensured, thereby enhancing the credibility and robustness of the research findings.

The selected sample size and period spanning from 2007 to 2022 can be considered appropriate for several reasons. Firstly, this 16-year timeframe provides ample scope for conducting a systematic analysis of long-term trends and patterns within the Indian aviation industry. Secondly, it encompasses various economic cycles and significant events such as GFC, economic reforms, shifts in aviation policies, and notably, the impact of the COVID-19 pandemic. These events are critical for understanding industry dynamics and resilience. Lastly, spanning over a decade and a half ensures the dataset's robustness in capturing both stable periods and volatile economic conditions, thereby offering a balanced perspective for conducting meaningful analysis and deriving policy implications.

It is important to note that post-2020, comprehensive and reliable information for many Indian airlines became unavailable due to the disruptions caused by the COVID-19 pandemic. Additionally, the schedules of numerous Indian airlines were severely affected, leading to a significant decline in revenue generation. Therefore, we ended up using an unbalanced panel data considering six airlines in 15 years (2007-2022), yielding a total of 79 observations. Table 1.3 offers a descriptive overview of the key variables under investigation within this study and Table 1.4 presents key insights derived from these descriptive statistics. In brief, the typical Indian airline exhibits a unit expenditure of approximately INR 25.01 billion per kilometer while being capable of generating approximately INR 24.96 billion per kilometer in total revenue thanks to an average of 15.7 million passengers travelled. We have applied consumer price index deflation to remove the effects of inflation, enabling accurate analysis of variables like income or costs in terms of their actual value relative to the years.

However, the study acknowledges certain limitation in data accessibility. Data beyond 2007 was not equally accessible for all airlines, potentially affecting robustness. On the other hand, data from 2007-2022 has been validated by the DGCA, and annual reports are audited by reputable firms, providing credibility. Primary data from airlines' websites presents constraints due to discontinuations or unavailability, including those influenced by the COVID-19 pandemic.

Table 1. 3

Descriptive statistics of variables of interest

Variables	Obs	Mean	Std. dev.	Min	Max
UREV	79	24.96	1.59	21.54	27.77
UEXP	79	25.09	1.50	21.71	27.76
STAFF	79	10458	9595.17	455	32407
PAX	79	13.5	15.8	0.31	87
AC	79	80	70	8.0	304
ALLIANCE	79	0.11	0.32	0.00	1.00
LCC	79	0.68	0.47	0.00	1.00
GFC	79	0.10	0.30	0.00	1.00
COVID	79	0.16	0.37	0.00	1.00
OWNERSHIP	79	0.49	0.50	0.00	1.00
UDANRCS	79	0.30	0.46	0.00	1.00

Notes: UREV and UEXP (both are in billion rupees per km) have been deflated using the consumer price index. The natural log of UREV, UEXP is taken, while STAFF, PAX and AC is measured without transformation. STAFF is in number of employees, PAX is measured in million and AC is measure in number.

Source: Annual reports of the sampled airlines.

We acknowledge that there may exist potential issues with the independent variables of Equation (1.2) that could also move together with *UREV*, or other variables being omitted from the estimation. To deal with such situations, we estimate the model using a dynamic panel specification of GMM. This GMM approach includes the lagged value of revenue as an explanatory variable, which helps absorb unobserved time-persistent effects and mitigates endogeneity arising from reverse causality. Additionally, airline fixed effects control for unobserved heterogeneity across carriers, while time dummies, for example *GFC* and *COVID*, capture macroeconomic shocks. Together, these modelling choices constitute our identification strategy, ensuring that the estimated relationships reflect causal effects rather than contemporaneous correlations.

The use of GMM, supported by Sargan tests, further ensures methodological robustness and validity. This approach effectively addresses endogeneity concerns, supporting reliable inference and interpretation of the empirical findings.

1.5 Empirical results and discussions

1.5.1 Model Selection

The Sargan test (Coef=0.156, p-value=0.028) strengthens the argument in the previous section that endogeneity is present in our data, and that *AC* and *UEXP* are valid instruments for the analysis (Roodman, 2009). The Hausman test is also used to determine whether FE, RE, or GMM is more appropriate for the analysis. Note that the null hypothesis of the Hausman test assumes that there is no difference between the results of the two models being examined; a statistical result for the Hausman test, therefore, suggests that the first model is better than the second one. Accordingly, the results reported in Table 1.4 show that GMM is the best model among the three. Note that the GMM approach effectively corrected for potential biases and provided more reliable parameter estimates, making it the preferred method in the analysis.

Table 1. 4

Hausman's test results

Test	**Hausman test statistic**	**Conclusion**
RE vs FE	0.999	RE is not better than FE
GMM vs RE	17.88**	GMM is statically better than RE
GMM vs FE	24.40***	GMM is statistically better than FE

1.5.2 Estimation results interpretation and discussions

Table 1.5 presents the estimated results derived from the IV regressions incorporating FE, RE and GMM models. Some important findings and their relevant discussions, which are based on the GMM results as the best model, are presented below.

Table 1. 5

Estimation results of IV regressions

	FE	RE	GMM
$UREV_{t-1}$	–	–	0.163** (0.081)
UEXP	1.704* (1.022)	1.491*** (0.346)	0.458*** (0.065)
STAFF	-0.248 (0.546)	-0.294 (0.179)	0.202** (0.088)
PAX	-0.263 (0.377)	-0.176 (0.194)	0.122** (0.043)
ALLIANCE	-0.003 (0.612)	-0.090 (0.260)	0.335** (0.147)
LCC	–	0.022 (0.203)	–
GFC	0.360 (0.553)	0.238 (0.280)	-0.192** (0.093)
COVID	0.034 (0.236)	0.044 (0.187)	-0.063 (0.084)
OWNERSHIP	-0.564 (0.520)	-0.632** (0.193)	-0.441** (0.167)
UDANRCS	-0.776 (0.853)	-0.579** (0.226)	0.148* (0.090)
Constant	-11.082 (15.480)	-6.722 (4.597)	5.976 (1.423)
χ^2	156201.74***	859.98***	856.66***

Remarks: ***, **, and * denote the significance levels at 1%, 5%, and 10%, respectively. LCC was omitted from RE and GMM models due to the multicollinearity issue. Standard errors are presented inside the brackets.

In GMM, *UEXP* is found to be statistically positively correlated to the Indian airline's unit revenue *UREV*, with a 1% increase in unit expenditure associated with a 0.458% increase in unit revenue. Given the inherently cyclical nature of the airline industry, this finding is in line with the results of Wojahn's (2012) and Alamdari and Morrell (1997). It also aligns with the airlines' increased expenditure on various events, thereby leveraging them to generate higher revenue (Gibson & Morrell, 2004; Singh et al., 2019).

This aligns with the expected causality of variables presented in Table 1.2. As unit expenditure is defined as the ratio of total expenditure by stage length, it thus suggests that Indian airlines should focus on acquiring new-generation aircraft with higher fuel efficiency, increasing seating capacity, and extended range capabilities (e.g., Das et al., 2020; Walters, 2018; West & Bradley, 2008). In the Indian airline industry, higher expenditure on marketing, expanding routes, and improving services can attract more passengers, leading to higher ticket sales and increased revenue. While there is a complex interplay between factors influencing airline competition and the pandemic's impact on industry dynamics, Sun et al. (2024) emphasised the growing importance of ancillary services and differentiated pricing strategies. Additionally, investments in technology and infrastructure can enhance operational efficiency, further boosting profitability.

The relationship between expenditure and revenue varies across industries, with some studies supporting the notion that higher expenditure leads to increased revenue, while others contradict this finding. For instance, in the textiles and clothing industry, Dunford et al. (2016) found that higher expenses related to design and marketing can lead to increased revenue by targeting premium market segments. Similarly, Hudáková and Bajus (2017) observed that in agriculture, high expenditure can yield high revenue. Schütz et al. (2020) demonstrated that for a European multinational utility company, strong expertise in purchasing can lead to cost savings and increased revenue. Additionally, Eller and Moreira (2014) showed that effective purchasing functions and supplier relationships across various industries in Latin America, specifically in a sample of 278 Chilean companies, play a crucial role in enhancing productivity and innovation, thus boosting revenue.

Conversely, higher expenditure does not always correlate with increased revenue. Zaharco et al. (2021) indicated that while optimising expenditure and improving operational efficiency are crucial for increasing sales revenue in agricultural enterprises, higher expenditure alone does not necessarily lead to higher revenue. In the oil and gas industry, Ogolo (2021) noted that higher expenditure raises the breakeven price required to achieve profitability, without directly increasing revenue. Similarly, Zwanziger and Mooney (2005) observed that in the healthcare sector, higher expenditure often results in slower growth rather than increased revenue. Notteboom and Vernimmen (2009) found that in the shipping industry, higher expenditure on bunker costs suggests that increased expenditure can lead to lower revenue. These observations underscore the complex relationship between expenditure and revenue across different industries, highlighting the need for strategic spending and operational efficiency to drive profitability.

Airline staff, denoted as *STAFF*, and unit revenue show a positive correlation, contrary to the expected causality of variables presented in Table 1.2. This suggests that airlines effectively aligning their staffing levels with operational needs tend to maintain positive revenue trends. According to the estimation results, a unit percentage increase in *STAFF* is associated with a 0.202% increase in unit revenue for operating airlines. Throughout the study period from 2007 to 2022, numerous Indian airlines underwent notable growth, prompting expansions in their routes and networks, evidently resulting in increased revenue. Naturally, this expansion necessitated greater staff involvement to accommodate the rising number of passengers and efficient operations. This is in alignment with the observations of Barbot et al., (2008) and Ginieis et al., (2020). Singh et al. (2019) pointed out that lower employee productivity, reduced ratios of in-flight personnel to total personnel along with lower aircraft utilisation also hinder the performance of state-owned airlines in the Indian context.

Passenger numbers, denoted by *PAX*, exhibit a positive correlation with the financial performance of the Indian airline industry. A one percent increase in passenger numbers typically results in a corresponding rise in unit revenue of approximately 0.122%. This is consistent with the anticipated causal relationships among the variables outlined in Table 1.2. Noted that passenger numbers have significantly increased in India since 2004, as evidenced by the data in Figure 1.1. Increasing passenger numbers drive revenue in the Indian airline industry through several key factors: market demand, competition, and service quality. Higher passenger numbers indicate strong market demand, enabling airlines to fill more seats per flight, thus maximising ticket sales and overall revenue (Sibdari et al., 2018). High demand also allows airlines to maintain or increase ticket prices without losing customers. In a competitive market, airlines that attract more passengers gain a larger market share, leading to economies of scale where the cost per passenger decreases, improving profitability (Alamdari & Morrell, 1997). Enhancing service quality (Camilleri, 2018), such as better in-flight experiences and customer service, attracts and retains passengers. More passengers also mean higher revenue from ancillary services like baggage fees, seat selection, in-flight sales, and loyalty programs. Additionally, increasing passenger numbers can justify expanding flight routes and frequencies, making travel more convenient and attracting even more passengers. Urbanisation further fuels this trend, as urban areas typically exhibit heightened demand for air travel due to increased business activities, tourism, and connectivity with other regions. Moreover, the growth of tourism has significantly contributed to the expansion of passenger volumes, consequently bolstering airlines' revenue streams (Dash et al., 2021; Iyer & Thomas, 2021).

The lagged variable of $UREV_{t-1}$ exhibits a positive correlation, suggesting that Indian carriers as a whole have shown a persistent increase in revenue over time. This could indeed be a valid explanation for the ongoing growth of the industry, where the financial performance of the previous year contributes to the success of the current year's performance. However, this situation may also be attributed to the rise of low-cost carriers, with low fares serving as the primary driver for sustained growth due to heightened competition in the country (Wang et al., 2018). Further, this underscores the importance of strategic investments in infrastructure, technology, and workforce development to sustain this upward trajectory.

Among the six dummy variables, *ALLIANCE*, *GFC*, *OWNERSHIP*, and *UDANRCS* emerged as statistically significant exhibiting influence over unit revenue. The partnerships reflecting via alliances, and connectivity schemes like UDAN, helped steered Indian airlines towards a more favourable revenue trajectory (see Das et al., 2020; Douglas & Tan, 2017). The importance of airline cooperation, particularly within alliances, is strongly notable due to its positive correlation with unit revenue. It's worth noting that at the time of this research, only the national carrier Air India was a member of the Star Alliance. Nevertheless, past evidences have consistently shown that joining such alliances leads to increased productivity, reduced fares, and boosted revenue (Douglas & Tan, 2017). Air India's revenue is derived not solely from domestic routes, but predominantly from international routes, where it boasts a more diverse network than any other carrier in India. Alliances contribute to market stability by reducing cutthroat competition, fostering sustainable pricing strategies, and driving industry innovation through the establishment of common standards. Meanwhile, the regional connectivity scheme, UDAN, demonstrates a notable inclination towards boosting unit revenue, highlighting the significance of the initiative. By facilitating the formation of air routes between Tier 2 and Tier 3 cities, connecting them to Tier 1 cities, the scheme encourages airlines to cater to regional passengers. Government subsidies backing flights to non-metro areas signify a promising prospect for countries with abundant non-metro cities, unlocking substantial potential for heightened passenger traffic. Additionally, the development of infrastructure could open up opportunities for tourism growth and increased commerce. Significance of *ALLIANCE* and *UDANRCS* corresponds to the anticipated causal relationship of variables outlined in Table 1. 2.

The dummy variable *OWNERSHIP* indicates that private airlines are statistically more likely to be effective in revenue generation. This aligns with observations of Singh et al. (2019) and Zhang et al. (2017). Private airlines, particularly the low-cost carriers, have experienced rapid network expansion due to factors such as appealing to price-sensitive passengers. Given that most Indian airlines are privately owned, there's a tendency for revenue generation to be a dominant feature of their ownership structure. This corresponds to the anticipated causal relationships among the variables outlined in Table 1.2. Furthermore, private airlines face less obstacles in accessing capital markets for investment and modernisation. And, as expected, the exogenous variables *GFC,* and *COVID* have had negative impacts on the financial performance of the airlines.

1.6 Policy implications and recommendations

The positive correlation between unit expenditure *UEXP* and unit *UREV* underscores the potential for revenue growth through investments in advanced technologies and efficient aircraft. Policymakers should incentivise Indian airlines to acquire new-generation aircraft with higher fuel efficiency, increased seating capacity, and extended range through tax incentives, subsidies or favourable financing options. These investments will enhance operational efficiency and environmental sustainability. Further, Sun et al. (2022a) emphasised that modern technologies such as data science and artificial intelligence (AI) can address critical challenges, especially during crises like a pandemic. Supporting technological investments, research and development in AI, and facilitating partnerships between technology firms and airlines are crucial steps. Robust human resource strategies are necessary, as indicated by the correlation between *STAFF* and *UREV*. Funding training programs and facilitating labour market flexibility can enable airlines to adjust their workforce according to demand changes. Increasing passenger volumes, highlighted by the correlation between *PAX* and *UREV*, requires policies promoting air travel, improving airport infrastructure, reducing air ticket taxes and enhancing urban-rural connectivity. Marketing campaigns to boost tourism and business travel can further increase passenger numbers (Das et al., 2020; Fageda et al., 2018).

Collaborative strategies among airlines supported by policies facilitating global alliances, bilateral agreements, code-sharing, and joint ventures, can enhance financial performance. While low-cost carriers typically don't join alliances, India's airline industry lacks a major full-service carrier comparable to Air India. Most other airlines in India operate as low-cost. Government support for the *UDANRCS* initiative is crucial for regional connectivity, including subsidies for non-metro flights and improving Tier 2 and Tier 3 city infrastructure. Promoting private sector participation and competition in the airline industry should be maintained, ensuring a level playing field, reducing bureaucratic barriers, and facilitating access to capital markets. Policymakers should develop contingency plans and financial support mechanisms to help airlines withstand economic shocks like the *GFC* and *COVID*, such as an aviation relief fund, temporary tax relief, and low-interest loans during distress periods. Integrating findings into policy through data-driven decisions, stakeholder engagement, and monitoring and evaluation is crucial for ensuring the sustainable growth and resilience of the industry.

One limitation of the study is that it focused on the relationship between *UEXP* (proxied by *AC*) and *UREV* and thus, did not examine network planning, fare structures, capacity allocation, or demand segmentation. As such, it cannot prescribe specific strategies for revenue maximization or cost efficiency. Nevertheless, the findings highlight that expenditure and resource allocation significantly influence revenue outcomes. For managers, this implies that careful monitoring of operational costs, staff deployment, and participation in schemes such as UDAN is important. Future research incorporating network decisions, pricing strategies, and demand segmentation would allow for a more comprehensive assessment of how different strategic paths, including revenue maximization, cost efficiency, or a balanced approach, affect managerial actions, data requirements, and performance metrics.

1.7 Conclusion

This research empirically investigated the influence of key drivers on the financial performance (proxied via unit revenue) of six Indian carriers from 2007–2022. This period encompasses significant phases in Indian aviation: expansion, turbulence (GFC 2008-2009 and COVID-19 pandemic in 2020), the insolvency of Jet Airways, and the privatisation of Air India in 2022. Using IV regression and GMM models, the study examined relationships between variables such as airline unit expenditure, staff numbers, passenger numbers, regional connectivity, alliance participation, ownership structure, and exogenous shocks including global financial crisis and the COVID-19 pandemic. The findings indicate a positive correlation between *UEXP*, *STAFF*, *PAX*, *ALLIANCE*, and *UDAN* with *UREV*. Conversely, *GFC* and *OWNERSHIP* exhibit a negative correlation with *UREV*. The study yields several noteworthy findings. Essentially, it's crucial to establish robust protective and supportive framework to ensure fair and equitable growth for all airlines in India, whether government-owned or private.

Although GMM has been used to address endogeneity, some issues may still remain; this limitation is acknowledged, and further investigation is recommended in future research. In addition, since the study focuses on a fair comparison between Indian airlines, greater emphasis is placed on the unit expenditure and unit revenue of the airlines; future studies extending to total expenditure/revenue may contribute to a broader understanding of the Indian aviation market. Further research should leverage and expand upon the methodologies and findings of this study, incorporating new variables like technology adoption and digital transformation, alongside deeper investigations into factors such as alliance participation and policy support. Extending the study period beyond 2022 will capture ongoing impacts, particularly the post-COVID-19 recovery phases, providing critical insights into industry resilience and adaptation strategies. Studies on other developing markets (e.g., Thailand or Vietnam) could also contribute to the literature.

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Chapter Two – Indian aviation: Airports

Preamble

This chapter builds directly on the analysis presented in Chapter 1, which explored the financial performance of Indian airlines and identified passenger traffic as a key driver of revenue and operational sustainability. The findings underscored the centrality of passenger demand in determining airline outcomes, especially during periods of market disruption and structural shifts within the aviation sector. While airlines are the primary beneficiaries of passenger and cargo demand, airports play an enabling role by serving as the physical infrastructure through which air traffic is managed. The ability of airports to maintain operations and handle traffic during crises has direct implications for the continuity and recovery of airline services. Recognising this interdependence, the current chapter shifts the analytical focus from airlines to airports, offering a broader view of the aviation ecosystem's resilience. It assesses how India's ten busiest airports responded to the disruptions caused by the COVID-19 pandemic. Using monthly data from March 2020 to 2024, the study examines passenger and cargo volumes as key indicators of demand. A BVAR model is used to compare actual post-pandemic performance with pre-COVID forecasts, while an OLOGIT model evaluates how airport-specific infrastructure and operational factors influenced recovery outcomes. Although this study focuses on major airports, its findings have broader relevance for India's regional connectivity goals. The ability of large airports to absorb shocks and sustain demand supports the development of a more integrated and resilient national aviation network. By anchoring this analysis in the demand-side dynamics introduced in Chapter 1, this chapter underscores the critical role of infrastructure and adaptability in ensuring aviation sector resilience during systemic disruptions, thereby informing future planning aligned with regional connectivity goals.

Study Two: Post-COVID-19 recovery and resilience in passenger and cargo traffic: A Bayesian vector autoregressive analysis of India's top 10 busiest airports

Publication status and candidate contribution

This study is currently being prepared for submission to a peer-reviewed journal, with *Economics of Transportation* identified as a suitable publication venue due to the relevance and scope of the research. The PhD candidate is the primary contributor and is listed as the first and corresponding author. The doctoral supervisors, who provided essential guidance, critical feedback, and support throughout the research process, are included as co-authors.

2.0 Abstract

This study evaluates the post-COVID-19 resilience of India's top ten busiest airports in terms of passenger and cargo traffic from 2016 to 2024. Using a BVAR forecasting approach, which applies Bayesian statistical methods to estimate multivariate time series models and improves forecast accuracy by incorporating prior information, the research compares actual airport performance with counterfactual forecasts to identify airports that exceeded, matched, or fell short of their pre-pandemic growth trajectories. The findings classify airports into outperformers, forecast achievers, and underperformers, highlighting the critical role of infrastructure in shaping operational resilience. Spearman correlation analysis and an OLOGIT model, which is suitable for analysing ordinal dependent variables and estimating the probability of categorical outcomes based on independent predictors, further reveal the relationships between infrastructure characteristics such as cargo terminals, runway capacity, and metro connectivity and resilience outcomes. The study shows that while India's major

airports demonstrated varying levels of recovery, those with stronger infrastructure and adaptive capabilities performed better. These insights offer valuable policy guidance for strengthening infrastructure, enhancing crisis preparedness, and promoting sustainable growth within India's aviation sector, particularly in light of the government's continued emphasis on regional connectivity through initiatives such as the UDAN scheme.

2.1 Introduction

Airport performance is typically assessed using operational, financial, and infrastructural indicators such as passenger traffic, cargo throughput, aircraft movements, revenue generation, and terminal and runway capacity. These metrics establish the baseline performance against which resilience can be evaluated. The airline industry demonstrates financial and economic resilience by adapting to disruptions, recovering from crises, and implementing strategic adjustments to ensure long-term sustainability (Tabares, 2021). Moreover, air travel remains the safest mode of transportation, with stringent regulations and continuous safety improvements minimising incidents and accidents (see Oster & Strong, 2013; Stoop & Kahan, 2020). However, pandemics like SARS (2002–2003), H1N1 (2009–2010), and COVID-19 (2019- 2023, with peak disruption through 2020) have significantly disrupted industries, especially aviation, where recovery poses substantial challenges (WHO, 2010, 2020, 2023) . Among these, the COVID-19 pandemic had the most profound impact, reshaping global industries and leaving lasting effects on business dynamics (Jackson et al., 2021; Sun et al., 2022; Tsui et al., 2021; Wu et al., 2024). According to Airports Council International (ACI, 2021), prior to the COVID-19 outbreak, the global airport industry was projected to generate approximately USD 188 billion in 2020; however, the impact of the crisis was unprecedented, with revenues falling by nearly USD 125 billion, a 66.3% reduction from the projected baseline. Governments' international travel restrictions further compounded the crisis, curtailing both passenger movement and freight transportation, forcing airports in cities such as Delhi, Mumbai, and Bangalore to significantly reduce their operational capacities (Dhillon, 2020; Dongare et al., 2020). Despite these challenges, aviation's critical role in emergency responses, such as the transportation of essential cargo and vaccines, remained evident (Sun et al., 2023; X. Wu et al., 2025).

As India emerges as the world's next fastest-growing aviation market (Boeing, 2024), supported by sustained GDP growth of 6.5–7% (OAG, 2024), it is poised to become the third-largest air passenger market within the next decade, according to IATA (IATA, 2025). This rapid expansion, driven by the growing middle class and India's rising global economic influence, highlights the increasing importance of understanding airport resilience. Initiatives like the regional connectivity scheme, UDAN, which aims to enhance accessibility in underserved regions (Das et al., 2020; Iyer & Thomas, 2020), further underscore the sector's adaptability and potential for growth. While UDAN's success has been varied as discussed previously, its role in linking regional airports to broader networks provides key insights into the resilience of India's aviation sector. However, the COVID-19 pandemic posed severe challenges to this growth trajectory. Mandatory lockdowns and border closures in March 2020 halted scheduled airline operations bringing India's aviation sector to a near standstill (Rawat, 2021). Domestic flights gradually resumed in May, with passenger numbers rising from 58,000 to over 500,000 by November 30, reflecting public confidence and the sector's resilience (Arora & Garg, 2020; Sidhu & Shukla, 2021). Aroskar et al. (2022) highlighted that the government's proactive vaccination drive and enhanced Point of Entry (PoE) surveillance contributed to improved crisis preparedness and early case detection. However, prolonged lockdowns severely impacted India's aviation network, including some of the world's busiest airports, some of which are in India. Passenger volumes plummeted dramatically (Vipin, 2012), leading to extensive aircraft groundings. The suspension of flights left airports largely inactive, causing significant disruptions in both passenger and cargo flows, thereby intensifying the broader challenges confronting the aviation sector (e.g., Ahmed et al., 2020; Sidhu & Shukla, 2021; Sobieralski, 2020). Gandhi and Gandhi (2020) observed that airports contended with uncertainty regarding their future operations, highlighting vulnerabilities in the sector's operational frameworks. These cascading challenges emphasised the importance of understanding and forecasting airport performance to guide resource allocation and recovery strategies.

According to Rodríguez and Olariaga (2024) the pandemic's unpredictability exposed limitations in traditional forecasting models, necessitating advanced approaches to navigate such crises effectively. Accurate forecasting of PAX and cargo performance is essential for infrastructure planning and resilience-building. This study employs the BVAR approach, known for its effectiveness in handling high-dimensional datasets and generating robust forecasts (e.g., Spencer, 1993; Woźniak, 2016; Zeng & Li, 2021). By comparing actual and forecasted PAX and cargo data, the study assesses the resilience of India's top 10 busiest airports under the COVID-19 pandemic. This gap analysis evaluates deviations between forecasted growth and actual performance, identifying airports that adapted effectively and those that struggled to meet targets. Advancements in statistical and econometric techniques have enhanced time series forecasting, reinforcing its essential role in informed decision-making (Athiyarath et al., 2020). For example, methods like BVAR incorporate statistical learning principles into forecasting frameworks.

In addition to examining COVID-19's impact on PAX volumes, this research explores its effects on cargo handling, a critical component of aviation resilience. During the pandemic, cargo operations emerged as a lifeline for global supply chains (Nath & Upadhyay, 2024), ensuring the transportation of essential goods, including medical supplies and vaccines. Indian airports played a vital role in maintaining these operations, highlighting the sector's adaptability under adverse conditions (Sun et al., 2023). However, challenges such as limited infrastructure and fluctuating demand underscored the need for robust planning and investment to enhance cargo capacity and efficiency. By analysing both PAX and cargo data, the study provides a comprehensive understanding of airport resilience, addressing gaps in existing literature.

Furthermore, the study evaluates the deviation between forecasted and actual performance under the assumption that the pandemic did not occur. This approach identifies key factors influencing airport resilience and highlights effective practices for managing disruptions. While traditional forecasting methods like principal component regression (PCR) and vector autoregressive (VAR) models have certain limitations, the BVAR approach, widely used in econometrics, incorporates prior information to improve predictive accuracy and robustness, particularly in data-constrained or uncertain contexts (Ahmed et al., 2010). Although not a machine learning (ML) technique, BVAR shares many characteristics of data-driven forecasting models. To further investigate the factors influencing airport resilience, an OLOGIT model was employed to examine how variations in airport infrastructure impact differences in PAX and cargo recovery. This analysis served as a robustness check for the BVAR-based classification of airports into outperformers, forecast achievers, and underperformers. This approach enhances the reliability of the results.

The findings of this research contribute to the broader discourse on crisis management and resilience in aviation. Policymakers can leverage these insights to develop targeted interventions, ensuring the long-term sustainability of India's aviation sector. As the global aviation industry continues to recover from the pandemic's impact, India's experience offers valuable lessons for other countries facing similar challenges. By fostering resilience and adaptability, the sector can better navigate future crises, supporting economic growth and connectivity.

This study is structured as follows: Section 2 reviews the relevant literature, Section 3 details the methodology and data employed, Section 4 presents the empirical analysis and discussion, and Section 5 concludes with policy implications, conclusions, and limitations.

2.2 Literature review

In industrial contexts, resilience is crucial for complex organisations dealing with hazardous processes. Dinh et al. (2012) emphasised the importance of resilience in preventing incidents despite robust risk management, particularly in technical operations. Kajitani et al. (2009) quantified resilience by examining the impact of disruptions to lifeline services, such as electricity and water, on industrial production. Tommaso et al. (2023) framed industrial resilience in the U.S. as the ability of sectors to recover from unexpected shocks, highlighting composite indicators to visualise sectoral performance and compare it to counterfactuals. Contextually, Borchert & Mattoo (2010) argued that services trade, particularly in India, showed greater resilience than goods trade, thanks to less dependence on external finance. Mandal (2012) examined supply chain resilience in India's IT industry, noting its importance due to increasing disruptions from natural and man-made disasters and the role of technology in enhancing agility. Namvar and Bamdad (2021) explored resilience as a safety management theory, integrating technical and social aspects to stabilise systems in industries like oil refineries and manufacturing. Building on this, Wood et al. (2019) assessed resilience in large organisations, such as defence forces, mapping resilience across various phases of threat events.

In aviation, resilience refers to the sector's ability to anticipate, adapt to, recover from, and thrive during disruptions or crises, including airlines, airports, regulatory bodies, and supporting systems. Zapola et al. (2024) highlighted that a widely accepted idea in resilience literature was the importance of systems responding quickly to environmental changes, which was particularly critical for the air transport network (ATN) in managing disruptive events such as the COVID-19 pandemic. Assessing resilience in aviation begins with analysing how the air transport network responds to such disruptions. Metrics such as aircraft movements, passenger throughput, and freight throughput were essential for evaluating resilience (see Guo et al., 2021). Comparing recovery patterns under various preventive and control strategies reflected an airport's recovery speed and its overall ability to withstand crises like the pandemic.

While the COVID-19 pandemic introduced an unprecedented structural break in global aviation, the use of pre-pandemic baselines—typically 2019 data—remains a widely accepted and methodologically sound approach in resilience studies. Numerous recent investigations have assessed airport and air transport resilience by benchmarking actual performance during and after the pandemic against expected or historical norms. For instance, Janić (2022) evaluated the resilience, robustness, and vulnerability of Heathrow and JFK airports by comparing 2020–2021 data with 2019 traffic figures, illustrating the continued viability of pre-COVID baselines as reference points in impact analysis. Similarly, network-based resilience assessments in China, Europe, and the United States have employed 2019 traffic levels to analyse recovery trajectories using both topological and operational indicators (Guo et al., 2023).

Further supporting this approach, Guo et al. (2021) compared pre- and post-pandemic airport performance to assess resilience, highlighting that airports with stronger emergency preparedness and control measures exhibited faster recovery from COVID-19 disruptions. Moreover, Wang et al. (2022) in a study published in *Aerospace*, employed a multi-phase resilience framework—originally developed for severe weather disruptions—to evaluate airport operational performance. The transferability of this pre- and post-disturbance comparative model across contexts affirms its methodological robustness.

Beyond these aviation-specific studies, broader resilience literature also endorses the practice of contrasting actual post-event performance with pre-event forecasts or projected trajectories. This comparative framework is instrumental in quantifying the extent of disruption and the deviation from expected growth, thereby offering insights into a system's absorptive capacity and adaptive recovery. Despite structural breaks, the observed divergence itself becomes a meaningful subject of analysis. As such, comparing post-COVID actual performance with pre-pandemic forecasts aligns with a recognized analytical tradition in resilience research and serves as a valid means of evaluating recovery outcomes and system robustness.

2.2.1 Resilience in aviation: Post-COVID-19 adaptation and global challenges

Serrano and Kazda (2020) provided a comprehensive analysis of the aviation industry's challenges and recovery strategies post-COVID-19 pandemic, emphasising financial, operational, and technological transformations at airports. Using a mixed-methods approach combining historical action, and inductive research, the study offered actionable insights into cost optimisation, contactless technology integration, and revenue diversification. While its practical focus is a strength, limitations include reliance on case-specific data and a lack of empirical validation for proposed measures. The study significantly contributed to aviation management literature by highlighting financial resilience, technological adaptation, and stakeholder collaboration as critical to recovery. However, future research could address gaps in quantitative modelling, regional disparities, and environmental implications to enhance its applicability.

Warnock-Smith et al. (2021) conducted a comprehensive evaluation of the pandemic's impact on China's domestic, European, and Asian air transport markets, highlighting significant disruptions in air travel, including fluctuations in capacity, revenue, and passenger traffic. Their study also emphasised the differing recovery rates between domestic and international markets.

Utilising robust datasets, the study effectively tracked demand and supply changes, yet the exclusion of data for November–December 2020 limited its temporal scope. The segmentation of analysis by routes, airlines, and premium vs. economy classes strengthened its practical relevance. However, the methodology's reliance on secondary data constrained the exploration of underlying qualitative drivers, and the absence of environmental impacts was notable. A significant contribution lay in its policy-relevant insights into the "Five One" rule and its implications for international recovery. The paper underscored the resilience of China's domestic markets compared to the protracted challenges of international routes. Nonetheless, future research could address gaps by integrating qualitative perspectives, broader market dynamics, and environmental concerns to enrich the understanding of aviation sector resilience.

Similarly, emphasising the critical role of governance and policy in recovery, Guo et al. (2021) conducted a comprehensive assessment of airport network resilience during global disruptions, using the Chinese (CAN) and European (EAN) airport networks as case studies during the COVID-19 pandemic. By applying complex network methodologies and leveraging real-world air traffic data, the study evaluated resilience and vulnerability from network and node-level perspectives, revealing that both CAN and EAN were scale-free small-world networks. While CAN displayed lower connectivity, it achieved higher recovery efficiency due to centralised policy enforcement, unlike EAN, which faced fragmented recovery strategies across nations. The methodology was a key strength, combining operational data with network theory to provide practical insights, although its exclusion of global networks like the U.S. and limited consideration of dynamic node strength and interdependencies were notable limitations. The study highlighted gaps in global aviation governance and collaborative recovery strategies while contributing valuable insights into bridging theoretical resilience metrics with practical recovery measures. Its findings underscored the importance of centralised and coordinated approaches to enhance airport network robustness, providing a foundation for future research to explore inter-regional networks and multi-dimensional resilience factors.

Focussing on the mitigating the impacts of pandemics, Tabares (2021) proposed the establishment of infectious disease-free zones within airport terminals through comprehensive health screening. Grounded in a multi-layered risk management approach that integrated aviation safety protocols with advanced health screening technologies, the study sought to restore passenger confidence and reduce dependence on disruptive measures like quarantines. The research was significant for its innovative integration of technology, operational logistics, and global standards, particularly its alignment with ICAO's Public Health Corridors (PHCs), to ensure a coherent and adaptive response to future health crises. Strengths of the study included its practical phased implementation plan and emphasis on scalability, but methodological weaknesses arose from its reliance on anticipated technological advancements and limited cost-benefit analyses. Furthermore, issues such as responsibility delegation, privacy concerns, and scalability in high-traffic scenarios remained underexplored. While the paper addressed critical gaps, such as the absence of globally standardised health protocols and the need for automated, cost-effective solutions, it provided limited empirical evidence to support its feasibility. Nonetheless, it made a substantial contribution by embedding health into aviation's safety and security paradigms, offering a foundational blueprint for future research and industry regulations aimed at resilient, pandemic-ready air travel.

A comprehensive evaluation of the COVID-19 pandemic's effects on global air transport, conducted by Arora et al. (2021), highlighted the significant disruptions caused by the pandemic, including sharp declines in passenger movements, cargo challenges, and financial losses. The study emphasised the aviation sector's unpreparedness despite lessons from prior outbreaks and proposed a framework for a coordinated response to future health crises. The proposed framework incorporated a multi-level threat response mechanism modelled on existing security regulations, advocating for global standardisation in pandemic protocols. This approach aimed to mitigate disease spread, ensure operational continuity, and enhance resilience across the sector. The study's strengths included its detailed categorisation of impacts and responses, use of empirical data, and integration of international guidelines, such as ICAO's CAPSCA (Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation) framework. However, methodological limitations included the absence of a detailed cost-benefit analysis for the proposed measures and insufficient empirical testing of the framework's feasibility. Additionally, the reliance on global coordination posed challenges due to varying national policies and priorities. The research also identified critical gaps, such as inadequate alignment of airport responses and limited global collaboration, underscoring the need for a unified pandemic preparedness strategy. By proposing a standardised response framework, the study made a significant contribution to the discourse on aviation resilience, offering actionable insights to safeguard the industry against future disruptions.

Su et al. (2023) used an ordered Probit model to analyse the unprecedented disruptions caused by COVID-19 in the European aviation sector, evaluating the recovery patterns and resilience of airports and airlines. The study identified critical factors influencing resilience, including the number of flights, market concentration, airline dominance at airports, and the impacts of policy measures such as the airport slot waiver. It revealed that higher airline concentration, and a significant presence of LCCs, positively influenced airport recovery, while full-service airlines (FSAs) also contributed to resilience. However, the study found that high-speed rail connectivity and stringent quarantine measures negatively affected recovery. The research was significant for its empirical approach and provided valuable insights into the determinants of resilience, offering actionable strategies for policymakers and stakeholders to enhance aviation recovery. Nonetheless, the study had limitations, such as the exclusion of financial and labour market variables, which could have provided a more holistic understanding of resilience, and its geographic focus on Europe, which limited generalisability. Overall, the study contributed to aviation literature by introducing a nuanced perspective on market concentration's role in resilience and suggesting adaptive strategies to mitigate future disruptions, highlighting the critical interplay between operational dynamics and external policies.

Wandelt et al. (2024) introduced the Global Airport Resilience Index (GARI), a new method for assessing the resilience of the global air transportation system, focusing on disruptions caused by targeted attacks and singletons. The study bridged the gap between oversimplified complex network models and computationally intensive simulation/optimisation methods. GARI provided a more nuanced assessment by incorporating both regional population effects and hub transfer activities, using data from 2023. The model's strength lay in its holistic approach, including ground transportation and alternative flights for community resilience. However, its reliance on simulations may have limited real-time applicability, and the focus on system-wide impacts may have overlooked airport-specific resilience factors. This research offered a valuable tool for stakeholders to enhance risk mitigation and operational efficiency, though future studies could refine the balance between model complexity and computational efficiency. A similar study from a simulation perspective, Mota et al.'s (2022) study on Mexico City's Multi-Airport System (MAS) during the pandemic, highlighted the recovery aspects of its three main airports for three different years (2021, 2025, and 2035), demonstrating that strategic infrastructure planning enabled the MAS to meet long-term demand effectively.

A research by Janić (2022) examined airport resilience, robustness, and vulnerability in North America and the United Kingdom, specifically focusing on the impact of the COVID-19 pandemic. The study introduced an analytical methodology that assessed operational, economic, social, and environmental performance indicators to evaluate cumulative and time-dependent resilience, robustness, and vulnerability. By applying this methodology to two of the busiest airports, London Heathrow (LHR) and New York's John F. Kennedy (JFK), the study revealed low resilience and robustness, along with high vulnerability across operational and economic indicators, highlighting the severe impact of the pandemic. A key strength of the research was its broad framework, which considered both internal disruptions, such as facility failures, and external events, including pandemics and natural disasters, while involving multiple stakeholders like airlines, air traffic control, and local communities for a more comprehensive analysis. However, the reliance on only two case studies limited generalisability, and the complexity of the models may have posed challenges for practical application by managers without specialised expertise. Despite these limitations, the study significantly contributed to aviation research by offering a quantitative framework for assessing airport resilience (both for passengers and cargo), which was valuable for strategic planning and risk management. It also underscored the lasting impacts of global disruptions like COVID-19 and recommended future research to expand the case studies, use recent data, and explore strategies to enhance resilience.

The study by Zapola et al. (2024) offered a pioneering framework for evaluating the resilience of airport passenger terminals (APTs) in response to disruptive events. The study's significance lay in its innovative approach to resilience metrics, with a particular emphasis on individual passenger and aircraft delays—factors often overlooked in traditional resilience assessments. The methodology employed fast-time simulation using a validated model of a Brazilian domestic airport, assessing various disruptive scenarios and recovery strategies. A key strength of the methodology was its systematic assessment process, incorporating new resilience metrics and accounting for individual delays, thereby offering a more nuanced understanding of airport resilience. However, the study's reliance on simulation models may have limited its applicability to airports with differing operational characteristics, and its focus on a single type of disruptive event, airport access blockage, may not have captured the full range of potential disruptions. The study identified important gaps in existing literature, particularly the lack of resilience assessments tailored specifically to passenger terminals and the need for metrics that account for individual delays. Its contribution was significant, providing a more comprehensive resilience assessment framework that enhanced airport resilience planning. Future research could extend this framework by investigating additional types of disruptive events and applying the methodology to a broader range of airports, thereby improving the framework's robustness and generalisability.

While these global studies offer valuable frameworks and insights, their applicability in developing contexts like India remains underexplored.

2.2.2 Resilience strategies for Indian aviation: A review of challenges and gaps

A study by Ganguly et al. (2020) on India's COVID-19 resilience, response, and impacts highlighted the profound socio-economic and public health challenges the country faced during the pandemic, emphasising critical implications for the aviation sector. While India's early lockdown and flight restrictions were necessary to curb the virus's spread, their abrupt implementation exposed systemic vulnerabilities, including the aviation industry's lack of preparedness for emergencies. The research, based on qualitative assessments of secondary data, effectively underscored the need for resilient systems but lacked sector-specific strategies, particularly for aviation. While this approach provided a broad perspective, the absence of primary data collection or in-depth stakeholder analysis limited its applicability for targeted policy recommendations in aviation. Although it identified logistical challenges, it missed the opportunity to explore aviation's critical role in pandemic mitigation, such as transporting medical supplies and enabling repatriation efforts. This gap limited its policy relevance, especially for aviation stakeholders. Nonetheless, the study emphasised the importance of integrating aviation and public health strategies to enhance crisis resilience, offering a foundation for future research on building adaptable and inclusive systems across interconnected sectors. Similarly, the findings echoed Gupta et al. (2022), whose study demonstrated that air travel significantly contributed to the initial spread of the virus, with districts hosting major airports reporting higher infection rates. This urban-centric transmission underscored the interdependence between urbanisation, transport networks, and pandemic diffusion, further highlighting the critical need for aviation sector resilience during health crises. The findings align with previous research, such as Gupta et al. (2022), which demonstrated air travel's significant role in the initial spread of the virus. Their study found that districts with major airports reported higher infection rates, reinforcing the interdependence between urbanisation, transport networks, and pandemic diffusion. This urban-centric transmission further underscores the critical need for aviation sector resilience during health crises.

Additionally, evidence from the Indian context revealed the significant impact of pandemics and economic uncertainties on the aviation industry, as analysed by Dash et al. (2021). Their study focused on the interplay between the aviation and hotel sectors, employing econometric tools like regression, Johansen Cointegration, fully modified ordinary least squares (FMOLS), and dynamic ordinary least squares (DOLS) to examine data from 2005 to 2020. The findings revealed that economic uncertainty significantly disrupted aviation market performance, with its impact overshadowing pandemic uncertainty. This observation aligned with existing literature on aviation markets in other countries, as highlighted in this study. Hotel cost volatility positively correlated with aviation activity, while fatalities from communicable diseases had adverse effects. Notably, pandemic-induced factors, apart from COVID-19, showed minimal impact. The study’s robust methodologies were a key strength, though its reliance on historical data limited long-term applicability. It also overlooked non-economic factors like government policies and infrastructure, crucial for resilience. By addressing aviation and ancillary industry interdependencies, the study emphasised the need for balanced economic and health policies but lacked qualitative insights from stakeholders, a key gap in understanding uncertainty absorption strategies.

Research by Rai et al. (2021) explored the interplay between resilience and sustainability in organisational contexts during the COVID-19 pandemic. It adopted a structured equation modelling (SEM) approach using primary quantitative data from 261 responses across industries in India. The research identified three critical aspects of resilience—crisis anticipation, organisational robustness, and recoverability—and evaluated their impact on two dimensions of sustainability: social and economic. The findings revealed that effective crisis anticipation fostered better resource utilisation and social responsibility, organisational robustness ensured resilience against disruptions while maintaining costs, and recoverability accelerated adaptation and stability. This study's key strength lay in its empirical focus on emerging economies, addressing a significant research gap. However, its reliance on quantitative data limited the exploration of qualitative insights, and its exclusion of environmental sustainability left the analysis incomplete. The authors acknowledged the need for a broader triple bottom line framework and suggested further studies incorporating mathematical modelling and qualitative dimensions. Despite its methodological limitations, this work provided a critical foundation for understanding how resilience supported sustainability, offering practical implications for industries and academics striving for long-term stability amidst crises.

The systematic literature review by Thounaojam and Dolla (2020) on resilience in public-private partnerships (PPPs) provided valuable insights into enhancing resilience in critical infrastructure sectors, with significant implications for airports. Airports, often managed under PPP frameworks for large-scale projects such as expansions and privatisations, faced unique challenges like demand fluctuations, technological obsolescence, and crisis vulnerabilities, making resilience a key focus area. The study systematically analysed 100 peer-reviewed papers from 1997 to 2022 using Scopus and Web of Science, applying a rigorous methodology that included thematic analysis across nine key areas, such as flexible contract mechanisms, risk allocation, governance strategies, and financial viability. The emphasis on dynamic adjustments to contracts and risk-sharing mechanisms, supported by theories like real options and game theory, was particularly relevant to airport PPPs, where long-term agreements had to adapt to disruptions such as economic downturns or geopolitical shocks. While the review highlighted the growing importance of resilience in the transportation sector, it lacked in-depth exploration of sector-specific testing mechanisms for airports and stakeholder collaboration strategies, which were critical for effective crisis response. Furthermore, although the study underscored the potential of flexible governance and dynamic contractual adjustments, its limited focus on operationalising resilience in real-world contexts left scope for further research. This review significantly contributed to PPP literature by identifying gaps and proposing strategies for improving resilience in airports and other infrastructure, offering a theoretical and practical foundation for navigating uncertainties and ensuring long-term sustainability. In contrast to this study, Gopichandran and Subramaniam (2020) critiqued the Indian public health system's inability to respond effectively to pandemics, particularly in light of the COVID-19 pandemic. The study emphasised practical reforms and presented a more action-oriented approach, calling for updates to policies and immediate structural changes within the healthcare system.

Despite the extensive body of literature on airport resilience in the wake of the COVID-19 pandemic, several critical gaps remain. Most existing studies focus on regional or national contexts, often treating airports as part of broader transportation systems rather than as distinct entities requiring independent resilience assessment. While innovative frameworks and resilience indices have been proposed, empirical validation across diverse airport settings, particularly in developing regions, remains scarce. Additionally, there is a notable gap in applying advanced forecasting methods, including econometric and statistical models, to assess airport resilience. Although financial, policy-driven, and network-based strategies are commonly discussed in post-pandemic aviation literature, significant gaps persist in cross-regional resilience comparisons, cargo-handling robustness, and the integration of multiple methodologies to evaluate long-term recovery trends. Furthermore, the role of infrastructure in shaping airport performance and resilience post-COVID-19 remains underexplored in India, where most studies focus on broad industry impacts rather than airport-specific challenges Notably, there is an absence of sector-specific resilience strategies tailored to both airports and airlines, particularly those addressing passenger and cargo dynamics in an integrated manner. These gaps underscore the need for further research that bridges methodological, empirical, and contextual limitations. A comprehensive examination of airport resilience, incorporating advanced forecasting models and a more nuanced understanding of cargo and passenger recovery, is essential for developing sustainable, crisis-ready strategies for the aviation sector.

2.3 Methodology

Advanced statistical models play a crucial role in addressing forecasting challenges, particularly during disruptions like the COVID-19 pandemic, where their ability to incorporate domain knowledge and handle structural breaks proves invaluable. Over the past decade, ML models have emerged as strong alternatives to classical statistical methods, especially in time series forecasting, which is essential for informed business decision-making (Ahmed et al., 2010; Athiyarath et al., 2020). While not a ML technique *per se*, BVAR incorporates Bayesian inference and regularisation to improve forecasting accuracy (Rudakouski, 2023). Unlike traditional econometric models that rely solely on frequentist estimation, BVAR leverages prior distributions to enhance parameter estimation and reduce overfitting—an approach conceptually similar to techniques used in ML (e.g., Athiyarath et al., 2020; Cramer & Thams, 2021; Kang & Hansen, 2018). Grounded in structured probabilistic modelling (Zeng & Li, 2021), BVAR effectively blends classical econometric rigour with flexible, data-driven forecasting, making it well-suited for complex and uncertain environments.

Among forecasting models, BVAR stands out as a credible alternative to the standard VAR model, particularly for analysing and comparing forecasted and actual trends in passenger (PAX) and cargo growth before and after the COVID-19 pandemic. The VAR model has long been a fundamental tool in economic forecasting due to its capacity to generate relatively accurate long-term predictions (Christiano, 2012; Sims, 1980). However, despite its utility, the unrestricted VAR model suffers from multicollinearity and a reliance on linear relationships (Spencer, 1993), limiting its ability to capture complex real-world dynamics, especially during periods of significant shocks like the COVID-19. BVAR addresses these limitations by integrating Bayesian priors, which mitigate overfitting and improve parameter estimation (Rudakouski, 2023). This makes BVAR particularly advantageous for smaller datasets, allowing for more precise and reliable forecasts (Song & Witt, 2006; Woźniak, 2016). By reducing the number of parameters required for estimation and enhancing forecasting accuracy (see Gupta & Sichei, 2006; Rudakouski, 2023), BVAR emerges as an optimal choice for assessing aviation resilience during disruptions.

This study applies a univariate autoregressive approach adapted from the BVAR methodology (Gupta & Sichei, 2006) to forecast PAX and cargo at individual airports. While BVAR is typically used for multivariate time series analysis (Berg, 2016), forecasting at the level of individual airports can still benefit from its ability to incorporate dependencies between passenger and cargo trends, as well as external shock. This approach aligns with the study's objectives of evaluating airport performance metrics such as resilience and recovery in the post-COVID-19 period. The analysis utilises historical monthly time series data from 2016 to

2024 for ten of India's busiest airports to assess variations in airport operations and forecast recovery trends.

Therefore, the following Equations (2.1) and (2.2) represent the autoregressive models used to forecast passenger traffic (PAX) and cargo volume, respectively.

$$PAX_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, Pax_{t-i} + u_t \quad (2.1)$$

$$Cargo_t = \delta_0 + \sum_{i=1}^{p} \delta_i \, Cargo_{t-i} + \varepsilon_t \quad (2.2)$$

where PAX_t *and* $Cargo_t$ represent the number of passengers (in persons) and cargo (in metric tonnes, MT) at time t respectively. α_0 and δ_0 are the intercepts (constant term), α_i and δ_i are the coefficients that represent the relationship between the current value and its lagged values, p is the number of lags included in the model, u_t *and* ε_t *are* the error terms, capturing random noise or unexplained variability.

While classical VAR uses ordinary least squares (OLS) or maximum likelihood estimation (MLE) for parameter estimation, BVAR employs Bayesian inference. BVAR combines prior distributions with the likelihood function to estimate posterior distributions of the parameters. Interestingly, Bayesian models have become increasingly popular within the transportation sector (Rodriguez-deniz, 2023), not primarily because of the benefits of Bayes' theorem, but due to the accessibility of these models through Markov Chain Monte Carlo[2] (MCMC) methods (for e.g., the Gibbs sampler algorithm), which enable more flexible and robust analyses, particularly in complex domains such as airport's forecast resilience (Hu, 2023; Washington et al., 2004). Hence, the coefficient of the i^{th} lag (α_i for passengers and δ_i for cargo) is estimated differently from the standard VAR model. Additionally, BVAR incorporates prior information

[2] The Monte Carlo method estimates the properties of a distribution through random sampling. In this approach, random samples are drawn from the distribution, and their properties, such as the sample mean, are calculated. MCMC extends this by generating samples sequentially, where each sample depends on the previous one, forming a 'chain.' This sequential dependency enables efficient exploration of complex distributions.

to shrink parameter estimates, mitigating overfitting and improving model stability, especially when dealing with inconsistent or sparse data. This regularisation enhances the robustness of BVAR, particularly when dealing with smaller or noisy datasets. This approach is particularly valuable for addressing irregularities, such as those caused by COVID-19 disruptions, as it enhances forecast reliability by generating probabilistic outputs that incorporate uncertainties in passenger and cargo trends. The Bayesian method is applied to Equations (2.1) and (2.2), leveraging prior distributions to represent initial beliefs about the parameters before observing the data. This approach assumes that the dataset may not provide comprehensive information across all dimensions, thereby enabling the incorporation of external knowledge or constraints to improve estimation accuracy (Ramos, 2003).

2.3.1 Data overview and key insights

Table 2.1 below presents the top 10 busiest airports[3] in India along with their key infrastructure details. The analysis compares their performance in passenger and cargo handling during the post-pandemic period against a baseline scenario constructed from their pre-pandemic performance (2016–2020). This baseline assumes no COVID-19 disruptions, and the collected data on passenger numbers and cargo, sourced from the Directorate General of Civil Aviation (DGCA) and Airports Authority of India (AAI) websites, serves as the basis for this comparison. Figure 2.1 illustrates the geographic distribution of these top 10 busiest airports in India, highlighting the locations across major metropolitan and economic hubs.

[3] The data from AAI (2016- 2024) includes total passenger traffic (covering all arrivals, departures, and transit passengers), total aircraft movements, and total cargo handled in metric tonnes, encompassing both freight and mail arriving at or departing from the airport.

Table 2. 1

India's 10 busiest airports by passenger and cargo traffic (2016–2024) along with infrastructure details based on AAI data

Airport Name	IATA Code	State	No. of Runways	No. of Domestic Terminals	No. of International Terminals	No. of Cargo Terminals	No. of Metro rail Terminals
Chhatrapati Shivaji Maharaj International Airport, Mumbai	BOM	Maharashtra	2	1	1	1	2
Kempegowda International Airport, Bangaluru	BLR	Karnataka	2	1	1	3	0
Rajiv Gandhi International Airport, Hyderabad	HYD	Telangana	2	1	1	1	0
Cochin International Airport, Kochi	COK	Kerala	1	2	1	1	0
Pune International Airport, Pune	PNQ	Maharashtra	1	1	1	1	0
Indira Gandhi International Airport, New Delhi	DEL	Delhi	4	2	1	2	1
Chennai International Airport, Chennai	MAA	Tamil Nadu	2	2	1	1	1
Netaji Subhas Chandra Bose International Airport, Kolkata	CCU	West Bengal	2	1	1	1	1
Sardar Vallabhbhai Patel International Airport, Ahmedabad	AMD	Gujarat	1	1	1	1	0
Dabolim International Airport, Dabolim	GOI	Goa	1	1	1	0	0

Figure 2. 1

Geographic distribution of the top 10 busiest airports in India

Source: Knowindia.net (2025)

As of August 2024, India has 34 international airports. Of these, 18 are managed by the Airports Authority of India (AAI), 6 operate under the public-private partnership (PPP) model, 7 are joint ventures (JV), and 3 are directly managed by state governments (AAI, 2024b). The airports are ranked based on both passenger traffic and cargo volume, with DEL (Indira Gandhi International Airport, New Delhi) being the busiest, handling the highest number of passengers, air traffic movements, and cargo operations. In contrast, GOI (Dabolim International Airport, Dabolim, Goa) has lower passenger numbers, partly due to the significant impact of the COVID-19 pandemic on tourism. Key factors contributing to the growth of India's aviation sector include a notable increase in air cargo and record-breaking passenger numbers at major airports such as DEL, BOM (Chhatrapati Shivaji Maharaj International Airport, Mumbai), and BLR (Kempegowda International Airport Bengaluru) in 2023.

The mean comparison presented in Table 2.2 and Table 2.3 summarise the passenger and cargo performance of airports across three periods: pre-pandemic, post-pandemic, and the entire period from 2016 to 2024. The passenger numbers and cargo volumes have been transformed using logarithmic values to reduce scale effects, address skewness, and enhance model performance. Gap Value (GV) represents the difference between post-pandemic and pre-pandemic mean values, highlighting the net change in airport performance after COVID-19. It quantifies the impact of the pandemic by showing whether airport metrics improved or declined in the recovery phase.

Table 2. 2

Passenger volume (millions) summary by airport and time period (2016–2024)

Airport Code	**Pre-pandemic**	**Post-pandemic**	**All period**	**Gap Value**
	2016-2019	2020-2024	2016-2024	
	Mean	Mean	Mean	
AMD	5.89	5.74	5.81	-0.15
BLR	6.36	6.22	6.29	-0.14
BOM	6.59	6.32	6.44	-0.27
CCU	6.2	6.04	6.11	-0.16
COK	5.91	5.65	5.77	-0.26
DEL	6.73	6.55	6.63	-0.18
GOI	5.8	5.55	5.66	-0.25
HYD	6.18	6.11	6.14	-0.07
MAA	6.23	5.97	6.09	-0.26
PNQ	5.82	5.64	5.72	-0.18

From the descriptive statistics for the period 2016–2024, which includes both pre-pandemic and post-pandemic phases, airports in India demonstrated varying levels of resilience. The Gap Value provides insights into the airports' ability to withstand and recover from the global disruption caused by the COVID-19 pandemic. DEL (Indira Gandhi International Airport, New Delhi) demonstrated the highest resilience, with a relatively small value of -0.18. This indicates that despite the pandemic's impact, DEL maintained a strong recovery trajectory, likely due to its robust infrastructure and strategic importance as the national capital's primary airport. Mumbai's BOM (Chhatrapati Shivaji Maharaj International Airport) experienced a more significant decline with a gap of -0.27. This larger gap suggests that BOM faced greater challenges in maintaining pre-pandemic passenger levels, possibly due to the severe impact of COVID-19 on Maharashtra, a key economic center. Bengaluru's BLR (Kempegowda International Airport) showed remarkable resilience with a gap of only -0.14, indicating a strong recovery in air traffic. This resilience may be attributed to Bengaluru's status as a major IT hub and the airport's modern infrastructure. HYD, (Rajiv Gandhi International Airport, Hyderabad) emerged as the most resilient among the analysed airports, with the smallest value of -0.07. This minimal difference between pre- and post-pandemic passenger volumes suggests effective management strategies and the city's growing importance as a business destination. MAA (Chennai International Airport) and COK (Cochin International Airport) both recorded a value of -0.26, indicating similar levels of impact and recovery challenges. This parallel trend might reflect regional factors affecting South Indian airports. Kolkata's CCU, (Netaji Subhas Chandra Bose International Airport) showed moderate resilience with value of -0.16, suggesting a relatively stable recovery in Eastern India's primary aviation hub. Smaller airports demonstrated varying levels of resilience. Goa's GOI (Dabolim International Airport) had a gap of -0.25, reflecting the significant impact on tourism-dependent regions. PNQ (Pune International Airport, Pune) and AMD (Sardar Vallabhbhai Patel International Airport, Ahmedabad) showed gaps of -0.18 and -0.15 respectively, indicating relatively better resilience among smaller airports. This analysis based on gap values reveals that while all airports experienced a decline in passenger volumes, their resilience varied significantly. Factors such as airport size, regional economic importance, and local pandemic management strategies likely contributed to these differences in resilience. The data underscores the need for tailored approaches to enhance airport resilience, particularly for smaller and tourism-dependent airports that showed larger gaps.

Table 2. 3

Cargo volume (metric tons) summary by airport and time period (2016–2024)

Airport Code	**Pre-pandemic**	**Post-pandemic**	**All period**	**Gap Value**
	2016-2019	2020-2024	2016-2024	
	Mean	Mean	Mean	
AMD	3.89	3.81	3.85	-0.08
BLR	4.48	4.5	4.49	0.02
BOM	4.87	4.79	4.82	-0.08
CCU	4.15	4.01	4.08	-0.14
COK	3.8	3.65	3.72	-0.15
DEL	4.9	4.86	4.88	-0.04
GOI	2.57	2.58	2.58	0.01
HYD	4.06	4.03	4.04	-0.03
MAA	4.51	4.42	4.46	-0.09
PNQ	3.52	3.34	3.42	-0.18

Similarly, in cargo handling, BLR demonstrated the highest resilience among major cargo hubs, with a gap value of 0.02, indicating that its cargo operations not only remained stable but slightly improved in the post-pandemic era. This could be attributed to Bengaluru's strong positioning as a logistics hub and its capacity for recovery. In contrast, MAA recorded a decline of -0.09, reflecting moderate challenges in restoring cargo volumes, potentially influenced by shifts in trade and logistics patterns. DEL, a crucial hub for cargo movement in North India, showed a minor value of -0.04, suggesting a relatively strong recovery, likely supported by its extensive freight-handling infrastructure. BOM saw a decline of -0.08, reflecting a slightly greater impact on its cargo operations, possibly due to the economic challenges Maharashtra faced during the pandemic. Meanwhile, HYD exhibited resilience with a value of -0.03, indicating only a slight dip in post-pandemic cargo activity. GOI maintained a stable value of 0.01, demonstrating minimal disruption in cargo operations despite its heavy reliance on tourism-driven air traffic. However, some airports faced more pronounced challenges. For example, AMD recorded a value of -0.08, while CCU and COK saw larger declines of -0.14 and -0.15, respectively, suggesting slower recoveries. PNQ experienced the steepest drop, with a value of -0.18, indicating the most significant pandemic-induced downturn in cargo volumes. These disparities in cargo resilience among Indian airports can be attributed to factors such as airport infrastructure, regional economic dependencies, and post-pandemic trade recovery dynamics.

The resilience scores for passenger (PAX_res) and cargo (CARGO_res) were derived by comparing actual post-COVID performance with the corresponding BVAR forecast values. Specifically, airports were categorised as underperformer (i.e., PAX_res=0 and CARGO_res=0) if their actual performance in terms of passenger and cargo were smaller than the forecasted values, respectively. Similarly, the resilience scores get a value of 1 for achievers (with actual values equal or close to the forecasts) and 2 for resilient (if actual values are indeed greater than the forecasts). These resilience scores are therefore categorical variables representing the relative recovery levels for passenger and cargo operations, which is further analysed in Section 2.4.

Post-pandemic, variability in both passenger and cargo volumes increased across airports, indicating the dynamic responses required to navigate fluctuating demand and operational constraints. While resilience was generally characterised by recovery to pre-pandemic levels or growth beyond, some airports experienced challenges in maintaining momentum, with certain regions showing more incremental recovery in cargo volumes and passenger traffic.

While descriptive statistics provide valuable insights into overall performance trends, they do not capture the dynamic interactions between variables. Therefore, this study prioritises findings derived from the BVAR analysis. The BVAR approach is specifically designed to model these interdependencies, allowing for the examination of how shocks propagate over time and affect airport resilience. By incorporating lag structures and cross-variable relationships, BVAR offers a more rigorous framework for assessing recovery patterns, distinguishing between short-term fluctuations and long-term trends.

To further explore the role of airport infrastructure in influencing performance outcomes, supplementary analyses using OLS and OLOGIT models were conducted. The following Equations (2.3) and (2.4) represent the OLS regression models employed to examine factors influencing the resilience of passenger traffic and cargo volume at airports. The outcomes and interpretation of these analyses are further elaborated in Section 2.4.3.

$$PAX\_res_i = \lambda_0 + \lambda_1 Runways_i + \lambda_2 Terminals_i + \lambda_3 Cargo\_Terminals_i + \lambda_4 Metrorail\_connectivity_i + \varepsilon_i \quad (2.3)$$

$$CAR\_res_i = \theta_0 + \theta_1 Runways_i + \theta_2 Terminals_i + \theta_3 Cargo\_Terminals_i + \gamma_4 Metrorail\_connectivity_i + \varepsilon_i \quad (2.4)$$

where PAX_res_i and CAR_res_i represents the resilience score for passenger and cargo traffic respectively, at airport *i*. $Runways_i$, $Terminals_i$, $Cargo\_Terminals_i$ and $Metrorail\_connectivity_i$ denote the number of runways, number of terminals, presence of cargo terminals, and number of metro terminals at airport *i* respectively. λ_0 and θ_0 are the intercepts, while ε_i represents the error term capturing unexplained variability.

Additionally, to account for the ordinal nature of the resilience scores, Equations (2.5) and (2.6) employ OLOGIT models that examine the influence of airport infrastructure variables on the likelihood of an airport falling within specific resilience categories for passenger traffic and cargo volume, respectively.

$$logit\big(P(PAX\_res_i \leq j)\big) = \tau_j - (\kappa_1 Runways_i + \kappa_2 Terminals_i + \kappa_3 Cargo\_Terminals_i + \kappa_4 Metrorail\_connectivity_i) \quad (2.5)$$

$$logit(P(CAR\_res_i \leq j)) = \zeta_j - (\psi_1 Terminals_i + \psi_2\, Cargo\_Terminals_i + \psi_3 Metrorail\_connectivity_i) \quad (2.6)$$

The log-odds of airport i having a resilience score at or below category j is modelled as a function of key infrastructure variables. The thresholds τ_j and ζ_j represent the estimated cut-off points that separate adjacent resilience levels. The coefficients (κ and ψ) indicate the effect of each variable on the likelihood of an airport exhibiting higher resilience, with more positive predictor values reducing the probability of falling into lower resilience categories. Due to estimation non-convergence, the variable *Runways* was excluded from the cargo resilience model. The final model retained *Terminals*, *Cargo_Terminals*, and *Metrorail_Connectivity* as predictors.

These models specifically assessed the relationship between infrastructure-related factors and airport performance indicators, such as passenger and cargo volumes. While the OLS model provided a general view of linear associations, the OLOGIT model captured more nuanced, ordinal shifts in performance levels, offering additional inferential insights. Although distinct from the BVAR approach, these supplementary analyses serve as robustness checks, offering complementary evidence on how infrastructure correlates with airport performance. This layered methodological approach ensures a more comprehensive and multidimensional evaluation of airport resilience, beyond what descriptive or single method analyses alone can offer.

2.4 Empirical analysis and discussion

The BVAR model estimation for PAX and cargo handling (in metric tons) at India's 10 busiest airports was conducted under the assumption of a counterfactual scenario without the COVID-19 pandemic. The model employed MCMC for posterior estimation, a sampling-based approach well-suited for Bayesian models and increasingly popular in transportation research (Washington et al., 2004). MCMC methods enable robust forecasts by addressing the inherent uncertainties in time series data (Rudakouski, 2023).

2.4.1 Bayesian vector auto regression

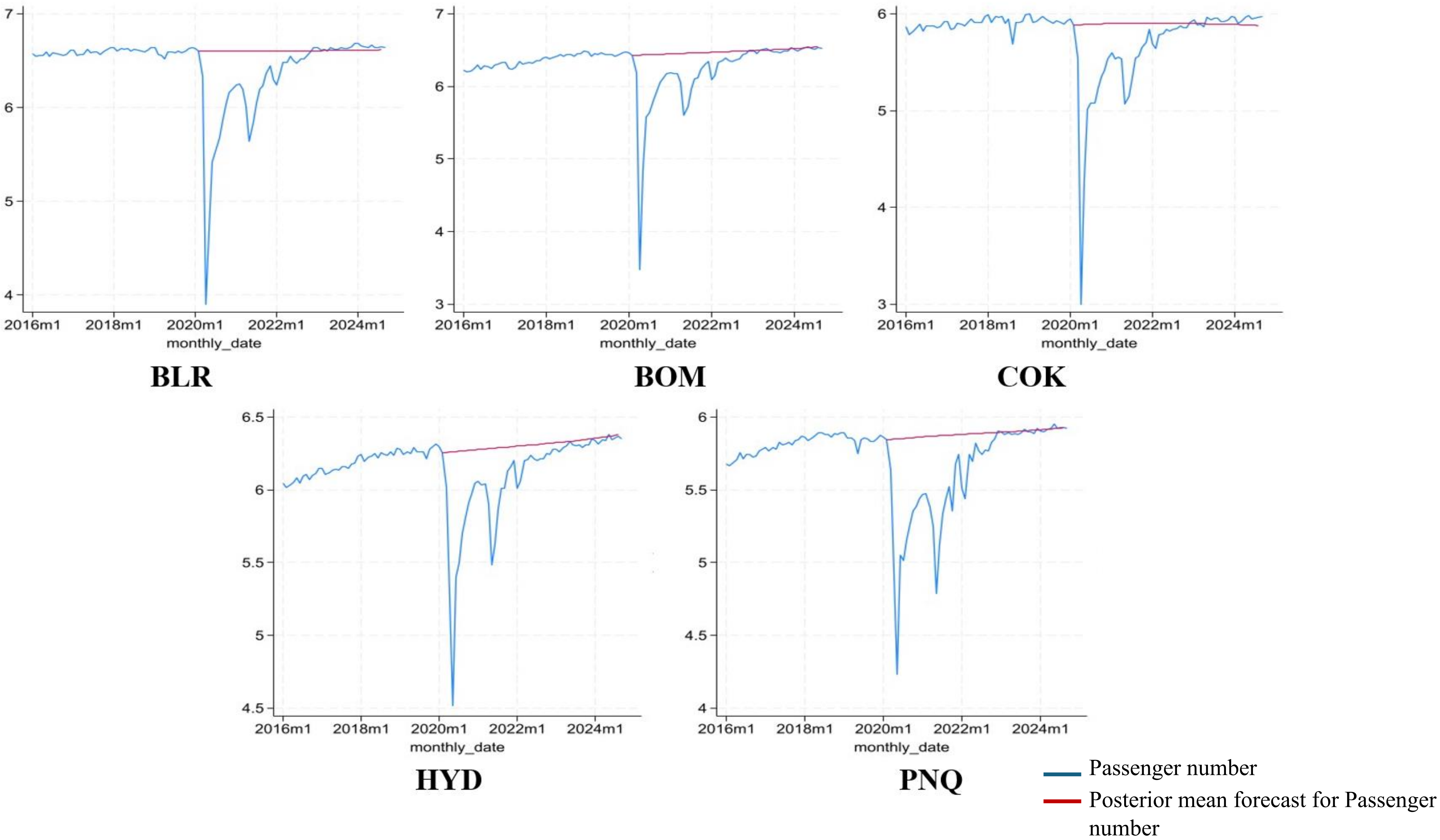
The comparison between the observed trends and the BVAR-generated forecasts allowed airports to be categorised into three groups: outperformers (airports exceeding forecasted recovery), forecast achievers (airports achieving moderate recovery), and underperformers (airports lagging behind expected recovery).

2.4.1.1 Outperformers

Unlike certain industries that demonstrated resilience during and after the pandemic, the aviation sector, particularly airports, was significantly impacted because of its direct connection with passenger movement and cargo operations. While other industries could operate with fewer disruptions, aviation faced unique challenges tied to health and safety protocols. For instance, although measures were envisioned to ensure that only passengers who passed all health checks could board flights to minimise long-distance disease transmission (Sun et al., 2022a), the pandemic created a pervasive fear psychosis, which suppressed passenger demand (Agrawal, 2021). It is apparent that the fear of contracting the virus among aviation workers, coupled with concerns over job security, further reduced productivity (Farooq et al., 2024; Rawat, 2021; Serrano & Kazda, 2020a). These intertwined challenges underscore the systemic vulnerabilities of the aviation sector during the pandemic, forming a critical context for understanding its overall impact on airports globally, including in densely populated countries like India. Figures 2.2 and 2.3 present the resilient airports, identified based on their PAX and cargo handling performance, respectively.

Figure 2. 2

The resilience growth-based PAX airports

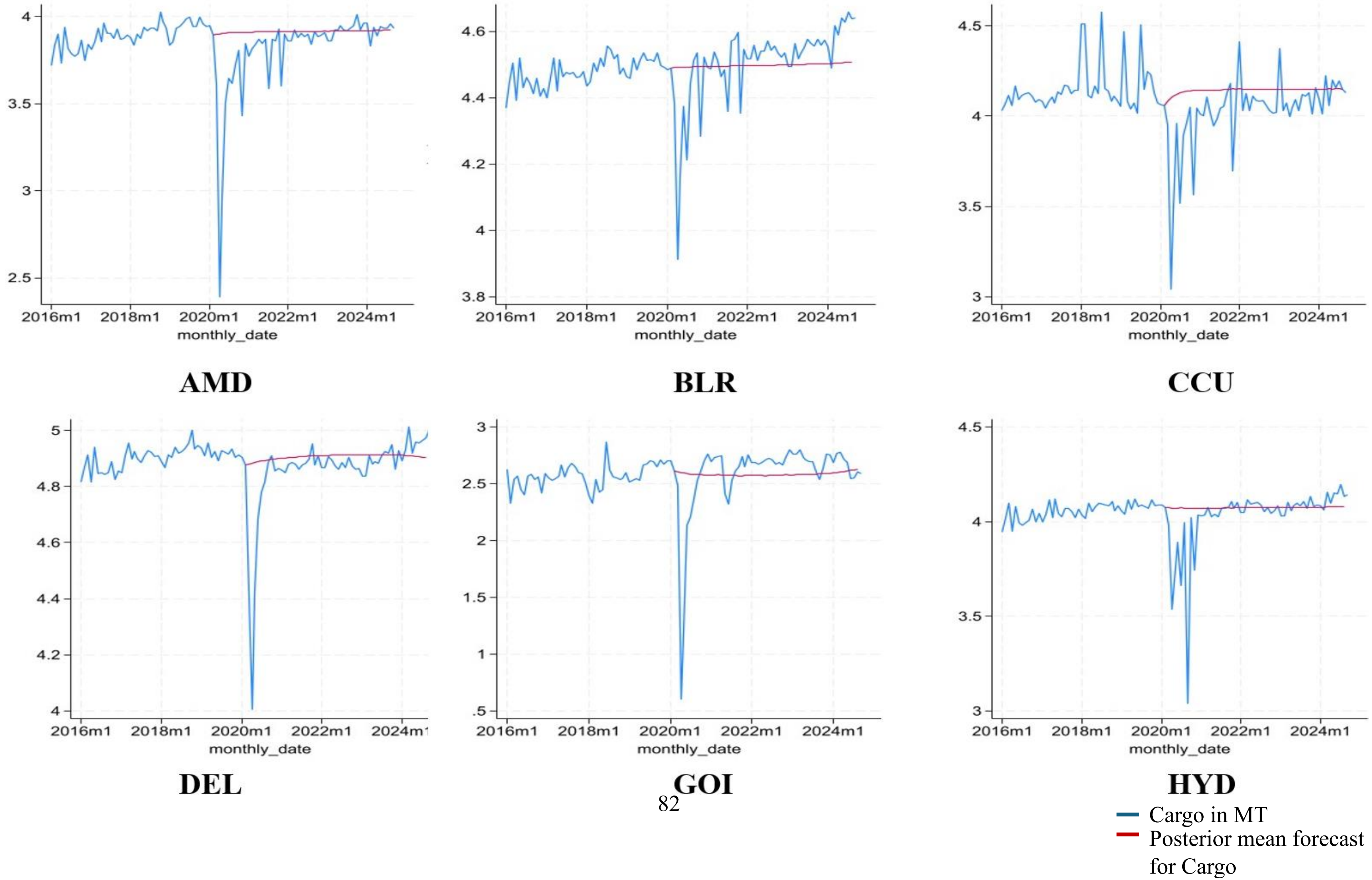


Five airports were identified as resilient in terms of passenger PAX handling: BLR, HYD, COK, BOM and PNQ. These results align with expectations, as major metropolitan airports demonstrated resilience alongside prominent non-metro airports like COK and PNQ. For instance, COK has consistently emerged as one of India's leading airports in terms of international passenger traffic, largely due to Kerala's sizable expatriate population (ICRA, 2023). The airport's well-developed infrastructure has played a crucial role in supporting this demand, enabling it to generate higher aeronautical and non-aeronautical revenue streams. This infrastructure-driven capacity has been instrumental in enhancing its resilience during challenging periods. In the fiscal year 2023-24, COK handled over 10.5 million passengers, accounting for 63.5% of Kerala's total air passenger traffic (CIAL, 2024), further underscoring the importance of robust infrastructure in sustaining operational performance. The resilience observed in these airports highlights the critical role that infrastructure plays in mitigating disruptions and ensuring adaptability during crises. Airports with advanced facilities such as intermodal connectivity with railway networks and comprehensive surveillance systems have proven to be better equipped to handle unforeseen challenges (e.g., Aroskar et al., 2022; Ganguly et al., 2020; Priyadharsini et al., 2021). For example, BLR's achievement of serving 74 domestic destinations in calendar year 2021, surpassing its pre-COVID-19 figure of 54 routes, reflects how investments in infrastructure enable airports to adapt and thrive even under adverse conditions, as highlighted by IAR (2022). This adaptability is not unique to India; similar trends have been observed globally. In the European aviation market, airports with well-developed infrastructure and high flight frequencies have consistently demonstrated greater resilience during disruptions (Boto-García & Pérez, 2023; Su et al., 2023). Airports served by both full-service carriers (FSCs) and LCCs benefit from diverse operational models that are supported by robust physical and technological infrastructure.

Moreover, government policies have further leveraged existing airport infrastructure to enhance resilience. The expedited vaccination programs implemented across India facilitated smoother travel for passengers by reducing health-related barriers to mobility. Major airports integrated proof-of-vaccination protocols into their operations efficiently, which contributed significantly to accelerating recovery processes. These measures were particularly effective at metropolitan airports where large-scale infrastructure allowed for seamless implementation. Together, these examples illustrate how better infrastructure directly translates into better resilience, enabling airports to maintain continuity and recover swiftly from disruptions.

Figure 2. 3

The resilience growth-based Cargo airports



Emphasising the focus on infrastructure, especially post COVID-19, many airports globally shifted focus from high-volume shipments to high-value goods, such as perishables and pharmaceuticals, highlighting the sector's evolving resilience strategies (Shrinivasan et al., 2024). In the domain of cargo resilience, six airports demonstrated resilience in cargo operations: AMD, DEL, GOI, CCU, BLR[4] and HYD. Interestingly, as noted by Dash et al. (2021), increasing pandemics have paradoxically led to a rise in aircraft movements, primarily driven by cargo operations. This trend is further supported by Farooq et al. (2024), who observed that several airlines expanded their cargo flight operations during such periods. For instance, GOI has demonstrated resilience in cargo operations by effectively utilising its existing infrastructure to sustain key exports, including agricultural produce (Chatterjee, 2024). Furthermore, despite economic uncertainties, a positive and significant correlation exists between cargo movements and aircraft activity, underscoring the importance of cargo operations in sustaining the aviation sector during challenging times. Major Indian airlines converted vacant passenger seats to accommodate cargo, a strategy also seen in China (see Li et al., 2023). This adaptive use of resources highlights the critical role of cargo operations in maintaining airport resilience, particularly in populous countries like India. India, as the largest global supplier of generic medicines and the top vaccine producer, played a key role in the COVID-19 pandemic. Producing 60 percent of the world's vaccines, India supplied over 298 million COVID-19 doses to around 100 countries through the Vaccine Maitri initiative by May 19, 2023 (PIB, 2023). Additionally, India's status as the world's largest supplier of generic drugs, including the widespread export of Hydroxychloroquine tablets for COVID-19

[4]BLR's cargo resilience is strengthened by its partnership with Envirotainer, which provides advanced temperature-controlled solutions to ensure an unbroken cold chain for pharmaceutical logistics. Pharmaceuticals account for 13% of the airport's annual international cargo, with key destinations including the US, UK, Australia, Canada, France, Vietnam, the Philippines, Germany, Nigeria, Algeria, Uganda, and Russia (PTI, 2021).

treatment (Gandhi & Gandhi, 2020) underscores the positive impact of the pandemic on cargo movements within the country.

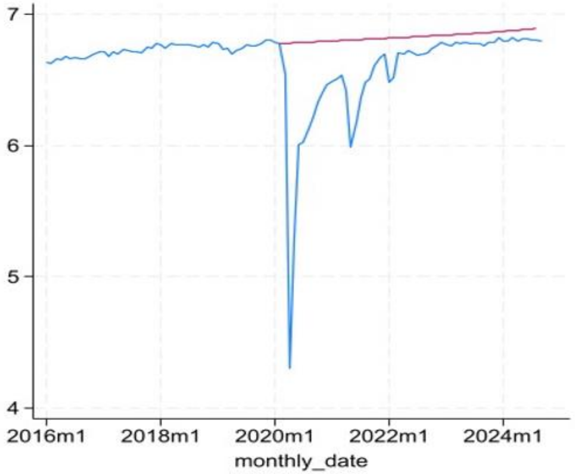
2.4.1.2 Forecast achievers

This category includes two metropolitan airports from each of two sections, passenger and cargo handling. For passenger traffic, MAA and DEL are included. For cargo operations, MAA and PNQ are included (see Figures 2.4 and 2.5). These airports are characterised by forecasted values closely aligning with actual output, reflecting their operational efficiency and strategic importance.

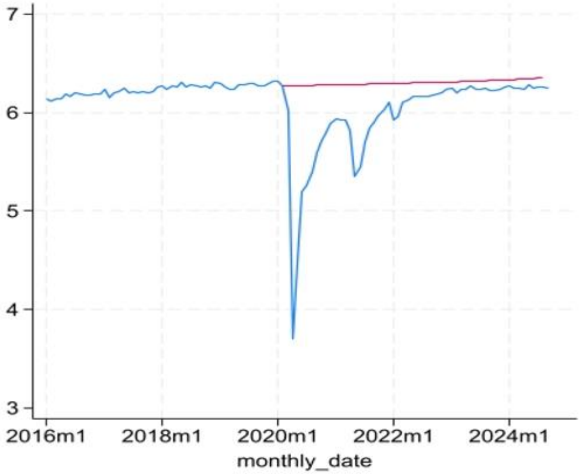
Metropolitan airports such as those in Chennai and New Delhi handle substantial passenger and cargo traffic volumes while maintaining extensive air traffic networks. MAA , for instance, is the fifth busiest in India by passenger traffic and aircraft movements, as well as the fourth busiest by cargo handled (AAI, 2024a). Despite their scale, these airports have not yet achieved their projected growth rates. However, with an anticipated acceleration in growth, they are expected to reach their forecasted performance levels in the near future. Intermodal transportation, such as high-speed rail in Europe and metro rail services in India, has complemented increased passenger connectivity to airports (see Albalate et al., 2015; Ricciutelli, 2012). For example, Delhi Airport is set to host India's first multi-modal interstate transport hub—integrating buses, metro lines, rapid rail transit systems, and an automated passenger mover, which is expected to significantly enhance regional accessibility and streamline passenger movement from neighbouring states, thereby strengthening the airport's operational efficiency and supporting its projected growth (Sinha, 2023).

Figure 2. 5

Passenger airports with moderate recovery



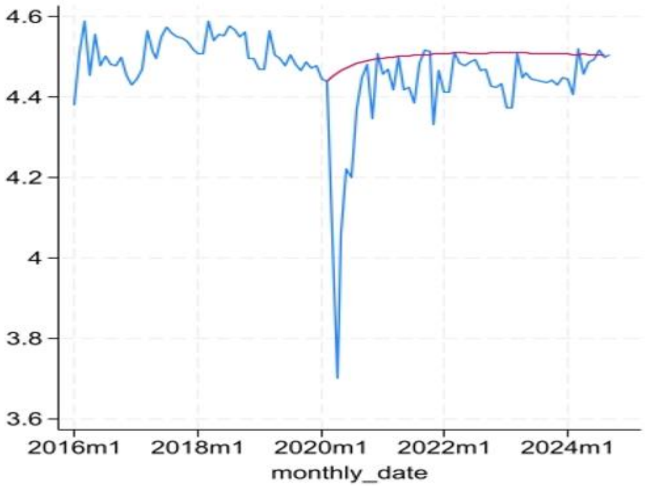
DEL



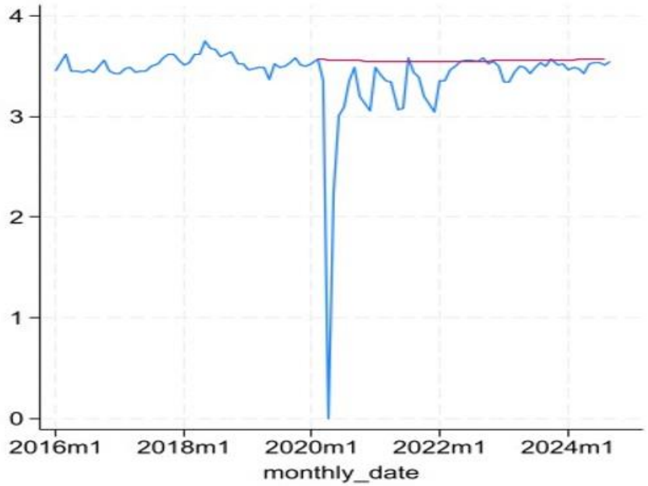
MAA

Figure 2. 4

Cargo airports with moderate recovery



MAA



PNQ

While it is widely accepted that the pandemic exposed significant gaps in urban public health systems (Mehta & Hingorani, 2021), the delayed adaptation to disruptions could be a contributing factor to these airports' inability to reach their expected performance levels on time. The swift implementation of surveillance measures and adaptations in PAX and cargo operations at resilient airports might have given the airports a head start. Airports that were slower in implementing these measures or faced logistical challenges in doing so may have been less resilient, even though they eventually managed to stabilise. During the COVID-19 pandemic, lockdowns were imposed primarily in major metropolitan cities, depending on the severity of the outbreak and its rate of spread. In response to these restrictions, the *"Vande Bharat Mission*[5]*"* played a crucial role in sustaining air travel and cargo operations (Rajan & Batra, 2022). National carrier Air India and its subsidiary, Air India Express, operated special domestic ferry flights exclusively for passengers repatriated under this mission. As of October 31, 2021, over 217,000 flights were conducted, facilitating the travel of more than 18.3 million passengers (PIB, 2021). This large-scale initiative not only addressed the needs of stranded individuals but also created momentum for airport operations and cargo activities, aiding the aviation sector's recovery. As noted by Nath and Upadhyay (2024) Indian air cargo volumes dropped significantly in early 2020 but rebounded later due to rising e-commerce and exports of essential items. These examples underscore the importance of robust infrastructure in fostering resilience and enabling airports to recover swiftly from disruptions while meeting growing demands for passenger and cargo services.

[5] As a response to the COVID-19 pandemic, the government of India initiated Operation Vande Bharat, a large-scale repatriation program designed to return stranded Indian nationals to their homeland.

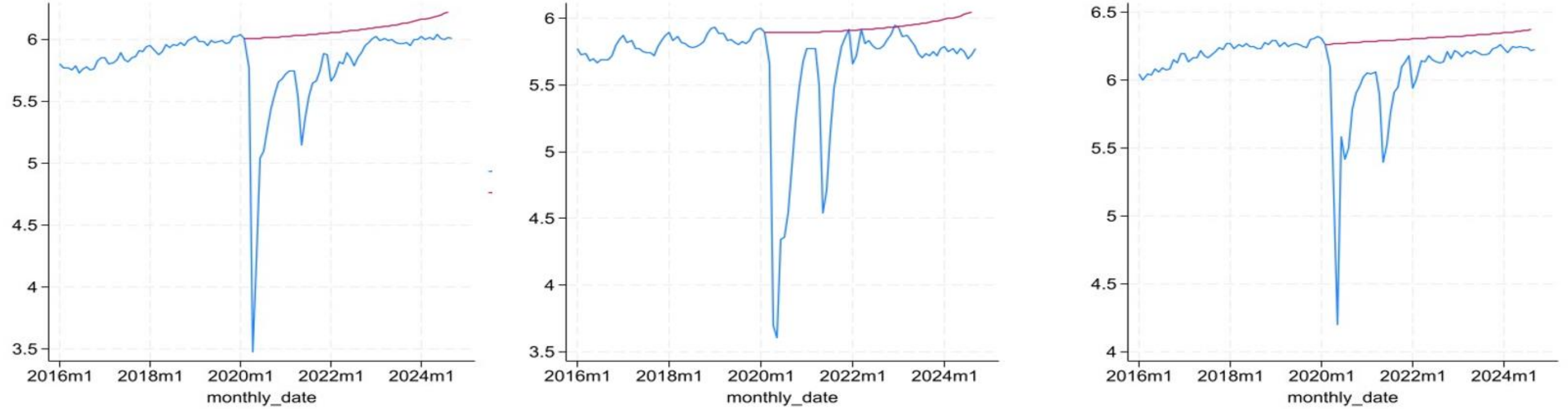
2.4.1.3 Underperformers

The airports lagging behind the expected recovery for passenger (PAX) handling are AHM, GOI, and CCU. In terms of cargo handling, BOM and COK airports have fallen short, as shown in Figures 2.6 and 2.7.

The underperformance of these airports aligns with the findings of Lordan et al. (2014), who observed that the vulnerability of air transport networks (ATN) to disruptions significantly impacts airline network connectivity. This also resonates with Zhou and Chen's (2020) assertion that identifying critical airports is essential for effective contingency planning. While some of India’s busiest airports demonstrated quick resilience during disruptions, others struggled to recover at the same pace due to infrastructure limitations. For instance, GOI experienced severe underperformance during the lockdown due to its heavy reliance on tourist arrivals and inadequate infrastructure to handle sudden changes in demand. The sharp decline in tourism significantly affected its operations, as highlighted by Dube et al. (2021) who noted that the pandemic had a pronounced negative impact on tourism-dependent airports, leading to lower-than-expected performance levels. Similarly, the cargo sector at these underperforming airports was adversely affected during the lockdown. Jackson et al. (2021) observed that India’s decision on March 25, 2021, to temporarily halt exports of COVID-19 vaccines in favour of prioritising domestic vaccinations further dampened airport cargo operations. Additionally, the "double lockdown" strategy implemented in certain regions, as identified by Theerthaana and Arun (2021), unintentionally accelerated the spread of the virus and led to stricter restrictions on airport activities. Despite air cargo gaining heightened importance during the pandemic due to restrictions on passenger flights, Nath and Upadhyay (2024) noted that the sector faced severe capacity constraints, infrastructure inefficiencies, and regulatory hurdles. These challenges limited its ability to cope with increased demand for essential goods and e-commerce shipments, underscoring the need for robust infrastructure to support resilience in airport operations.

Figure 2. 6

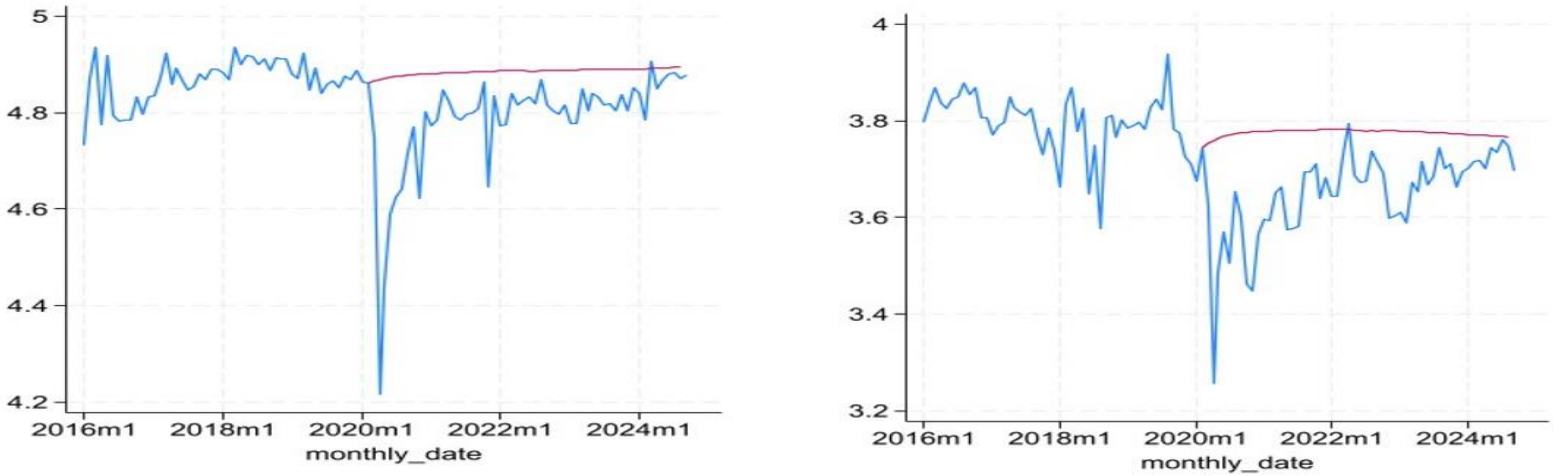
Airports with lagged recovery in PAX handling



AMD **GOI** **CCU**

Figure 2. 7

Airports with lagged recovery in Cargo handling



BOM **COK**

Table 2.4 provides a summary of airport resilience findings, categorising airports into outperformers, forecast achievers, and underperformers based on their passenger and cargo performance. These findings highlight how vulnerabilities in infrastructure such as inadequate capacity and inefficiencies can hinder recovery efforts, emphasising the need for infrastructure improvements to mitigate future disruptions.

Table 2. 4

Summary of airport performance in passenger and cargo resilience

Category	**Airports (Passenger performance)**	**Airports (Cargo performance)**
Outperformers	Kempegowda International Airport, Bengaluru	Sardar Vallabhbhai Patel International Airport, Ahmedabad
	Rajiv Gandhi International Airport, Hyderabad	Kempegowda International Airport, Bengaluru
	Cochin International Airport, Kochi	Indira Gandhi International Airport, Delhi
	Chhatrapati Shivaji Maharaj International Airport, Mumbai	Dabolim International Airport, Goa
	Pune International Airport, Pune	Rajiv Gandhi International Airport, Hyderabad
		Netaji Subhas Chandra Bose International Airport, Kolkata
Forecast achievers	Chennai International Airport, Chennai	Chennai International Airport, Chennai
	Indira Gandhi International Airport, Delhi	Pune International Airport, Pune
	Sardar Vallabhbhai Patel International Airport, Ahmedabad	Chhatrapati Shivaji Maharaj International Airport, Mumbai
Underperformers	Dabolim International Airport, Goa	Cochin International Airport, Kochi
	Netaji Subhas Chandra Bose International Airport, Kolkata	

2.4.2 Infrastructure–resilience relationship: Spearman correlation approach

To further understand the relationship between airport infrastructure and resilience, a Spearman correlation analysis was conducted. Spearman's rank correlation coefficient is more effective as it is a nonparametric measure that assesses the strength of a monotonic relationship between variables without assuming a linear relationship or normal data distribution (Hauke & Kossowski, 2011). Given the nature of the dataset, where variables such as airport infrastructure and resilience may not follow a normal distribution (Bishara & Hittner, 2012), Spearman's correlation provides a more reliable measure of association compared to Pearson's correlation. The results, as presented in Table 2.5 shown below, highlight key associations between PAX and cargo resilience and various airport infrastructure features, providing deeper insights into the observed trends. Passenger resilience (PAX_res) represents the airport's ability to recover passenger traffic following a disruption, measured by comparing actual passenger volume trends against forecasted or pre-pandemic levels. Similarly, Cargo Resilience (CARGO_res) reflects the airport's capacity to restore cargo handling operations post-disruption, assessed based on deviations in cargo volume from expected recovery patterns. The overall resilience of an airport is also influenced by its infrastructure as observed, which includes essential elements such as runways (Runways), terminals (international and domestic, as noted as Terminals), cargo terminals (Cargo_Terminals), and Metrorail connectivity (Metrorail_connectivity). The following table details these correlation results.

Table 2. 5

Spearman correlation matrix of airport resilience and infrastructure details

Variables	PAX_res	CARGO_res
PAX_res	1	
CARGO_res	-0.537***	1
Runways	0.087**	0.228***
Terminals	0.041	-0.345***
Cargo_Terminals	0.364***	0.169***
Metrorail_connectivity	-0.128***	-0.267***

Remarks: *** and ** indicate statistical significance with *p*-values of ≤ 0.01 and ≤ 0.05, respectively.

Based on the Spearman correlation matrix, several noteworthy relationships emerge between airport infrastructure variables and resilience indicators for both passengers (PAX_res) and cargo (CARGO_res). A negative relationship is observed between PAX_res and CARGO_res, suggesting a potential trade-off in resilience between passenger and cargo operations across the studied airports. Among infrastructure variables, the number of runways (Runways) shows a consistent positive association with both PAX_res and CARGO_res, indicating that greater runway capacity may enhance the overall resilience of airports, particularly in supporting cargo operations. In contrast, the number of terminals (Terminals) does not show a meaningful link with PAX_res but appears to be negatively related to CARGO_res. This may imply that terminal expansion primarily benefits passenger services (domestic and international) and may not directly contribute to cargo resilience. The availability of a dedicated cargo terminal (Cargo_Terminals) is positively linked with both resilience measures, reinforcing the importance of specialised infrastructure in maintaining stable operations during disruptions. Interestingly, metro connectivity (Metrorail_connectivity) shows a negative relationship with both PAX_res and CARGO_res, suggesting that airports with higher integration into metropolitan transport networks might encounter operational challenges or capacity constraints under stress. Overall, these findings highlight the varied influence of infrastructure attributes on airport resilience, underscoring the value of targeted investments—particularly in cargo infrastructure—to strengthen operational robustness across both passenger and cargo functions. It is important to note that the Spearman correlation serves as an exploratory diagnostic rather than conclusive evidence of a structural trade-off. The observed negative association between PAX_res and CARGO_res highlights that high passenger resilience does not necessarily coincide with high cargo resilience—a relationship that is examined in more depth using the OLOGIT model.

2.4.3 Comparing OLS and OLOGIT approaches to airport infrastructure resilience

As previously expressed in Equations (2.3) and (2.4) for OLS, and Equations (2.5) and (2.6) for OLOGIT, the nature of the dependent variables, PAX_res and CARGO_res as ordinal indicators of resilience (i.e., *Outperformers*, *Forecast Achievers*, and *Underperformers*) necessitates the use of an OLOGIT model. While OLS assumes a continuous and normally distributed dependent variable, this assumption does not hold for ordinal categories, making OLS less suitable in this context. In contrast, the OLOGIT model accounts for the ordered structure of the resilience levels by estimating the log-odds of being in a higher resilience category and incorporating threshold effects between categories. This results in more robust and interpretable estimates. Table 2.6 provides a comparative overview of the OLS and OLOGIT estimates, underscoring the superior fit and appropriateness of the OLOGIT model for analysing ordinal outcomes such as PAX_res and CARGO_res.

Table 2. 6

Comparison of OLS and OLOGIT estimates for airport resilience outcomes

	OLS		OLOGIT	
	PAX_res	**CARGO_res**	**PAX_res**	**CARGO_res**
Runways	-0.427*** (0.043)	0.977*** (0.024)	-1.701*** (0.142)	-
Terminals	0.323*** (0.057)	-1.024*** (0.032)	0.317** (0.153)	-1.551*** (0.154)
Cargo_Terminals	0.700*** (0.04)	-0.305*** (0.022)	3.398*** (0.279)	1.408*** (0.154)
Metrorail_connectivity	0.249*** (0.044)	-0.982*** (0.025)	0.653*** (0.120)	-1.140*** (0.107)
Constant (_cons)	0.260** (0.124)	2.854*** (0.069)		

Remarks: Statistical significance is denoted by ***, **, and * representing p-values of ≤ 0.01, ≤ 0.05, and ≤ 0.1, respectively.

In the OLOGIT results, Runways shows a statistically significant negative relationship with PAX_res, suggesting that an increase in the number of runways may be associated with lower passenger resilience. This counterintuitive finding may reflect operational complexity at larger airports with multiple runways, where managing disruptions becomes more intricate and recovery slower. Interestingly, this variable was omitted from the OLOGIT model for CARGO_res due to non-convergence—potentially because runway availability does not significantly discriminate between cargo resilience levels or is highly collinear with other infrastructure variables in the model. We leave the answer to future studies when more data is available.

Cargo_Terminals emerges as the most consistent and influential factor, displaying a strong positive association with both PAX_res and CARGO_res. This underscores the critical role of integrated cargo facilities in supporting operational flexibility and adaptive capacity, even in passenger-centric environments. Metrorail_connectivity also plays a significant but divergent role—positively influencing PAX_res, while negatively affecting CARGO_res. This contrast may stem from the fact that metro access primarily enhances passenger mobility and airport accessibility, whereas cargo operations may experience spatial limitations or regulatory frictions in densely built-up, metro-connected environments. Terminals exhibits mixed effects as it enhances PAX_res, yet has a strong negative impact on CARGO_res. This divergence may reflect a tendency to prioritise passenger-centric services in terminal design and expansion, potentially at the expense of efficient cargo handling. These trade-offs highlight the need for differentiated infrastructure strategies to support both dimensions of resilience.

Overall, the OLOGIT results, reinforced by the findings of the BVAR analysis, affirm that infrastructure plays a central role in shaping airport resilience. However, its effects are nuanced and operation-specific, with certain assets bolstering passenger resilience while undermining cargo adaptability, or vice versa. This multidimensionality confirms the utility of the OLOGIT model in capturing the ordered and differentiated nature of resilience outcomes.

2.5 Policy implications, conclusion and limitations

The global aviation industry faced significant disruptions due to the unprecedented challenges brought about by the pandemic, as highlighted by ICAO. While the crisis disrupted established norms at many airports, it also fostered creative and adaptive solutions within the airline industry. One could argue that India, too, endured comparable impacts on its air transport sector, evident in airport closures, operational breakdowns, and the imposition of nationwide lockdowns. The analysis of Indian airports' resilience to PAX and cargo demand disruptions during the pandemic underscores the importance of adaptive strategies for recovery and preparedness. Central to such preparedness is the development and modernisation of airport infrastructure, which underpins both operational continuity and service efficiency. While many airports are on the path to recovery, the findings highlight the need for an integrated approach to enhance system-wide resilience against future disruptions. Policymakers and aviation stakeholders should prioritise the development of flexible contingency frameworks capable of addressing diverse disruptions such as pandemics, natural disasters, and security breaches. These frameworks should focus on dynamic resource allocation, effective communication protocols, and robust passenger/cargo management strategies. Additionally, periodic reviews and scenario-based simulations are vital for refining these frameworks, ensuring they remain responsive to evolving challenges. Drawing lessons from recent disruptions and proactively embedding them into operational policies can significantly bolster the sector's ability to withstand and recover from future crises. Second, the adoption of advanced technologies is pivotal in enhancing operational efficiency, improving forecasting accuracy, and facilitating real-time decision-making. This includes leveraging data analytics, AI-powered predictive models, and advanced communication systems (see Nath & Upadhyay, 2024; Sun et al., 2022), accelerated adoption of biometric check-in solutions (Amankwah-Amoah, 2021), revised layouts and touchless technologies (see Sun et al., 2022). However, bureaucratic hurdles remain a significant challenge, particularly in areas such as technological investment and implementation. Streamlining regulatory frameworks and fostering enhanced inter-agency coordination could improve the sector's adaptability to changing conditions and incentivise technology adoption. Third, investments in training and development programs for airport personnel are necessary to enhance crisis management capabilities, particularly in tourism-focused airports as well as managing cargo. Specialised training in passenger handling and cargo logistics could strengthen overall airport resilience. The observed decline in cargo resilience at key hubs such as BOM, COK, and MAA underscores the importance of targeted cargo-handling policies. Moreover, the empirical results presented in Table 2.6 indicate that cargo performance is a significant factor influencing both passenger and cargo resilience.

Therefore, modernising cargo infrastructure through measures such as adopting automated storage systems and improving multimodal logistics connectivity may be crucial for strengthening overall airport resilience. Tailored subsidies and public-private partnership models can attract greater investment in air freight facilities, ensuring a robust supply chain during economic shocks or pandemics. The emergency response capabilities of a country during public health crises significantly influence the speed of aviation recovery. From a policy perspective, while the ICAO framework, including initiatives such as PHCs and the phases of the Council Aviation Recovery Task Force (CART), offers a robust global structure, its effectiveness is undermined by the reliance on individual country regulations (see ICAO, 2020, 2021; Tabares, 2021). To enhance aviation resilience in a populous country like India, these frameworks must be uniformly enforced and better integrated into national policies. Additionally, explicit comparisons with countries experiencing similar aviation growth profiles (e.g., China, Brazil, Indonesia and the United States) can provide valuable insights into addressing India's unique challenges and refining its strategies. This approach will ensure consistent implementation within the country and stronger alignment with international practices during public health crises.

This study utilised a BVAR model to evaluate the performance of India’s busiest airports in terms of passenger and cargo resilience from 2016 to 2024. The analysis examined the pre-COVID-19, post-COVID-19, and overall performance of these airports by comparing forecasted growth trajectories, assuming no pandemic, with actual performance. The study underscores the extent to which the pandemic disrupted operations and highlights the varying levels of resilience demonstrated by different airports. Findings indicate that most airports showed moderate to high resilience, with some achieving forecast levels within a short period, underscoring the adaptability of Indian airports. Based on their ability to meet forecasted performance levels, airports were categorised as outperformers, forecast achievers, and underperformers. The results emphasise the resilience of India's airport infrastructure, reflecting a strong recovery trajectory in both passenger and cargo operations. However, targeted efforts in modernising cargo facilities, addressing bureaucratic inefficiencies, and investing in advanced technologies and workforce training are critical to sustaining and enhancing this resilience. Policymakers and industry stakeholders must collaborate to implement these measures, ensuring the sector's preparedness for future disruptions.

This study highlights the critical role of robust airport infrastructure in enabling airlines to sustain profitability and effectively navigate disruptions, particularly in the context of post-COVID-19 recovery. Airports with the capacity to efficiently handle both passenger and cargo traffic play a pivotal role in supporting the operational and financial stability of airlines. This interdependence becomes especially apparent during times of disruption. India's regional aviation aspirations continue to face challenges due to infrastructure inadequacies, particularly at smaller and regional airports, which remain a major barrier to sustainable aviation growth. The findings underscore a central theme: resilient and well-developed airport infrastructure is essential not only for enhancing airline profitability and boosting passenger and cargo demand, but also for supporting the long-term success of regional connectivity initiatives. By evaluating the resilience of India's busiest airports in terms of passenger and cargo performance, this analysis reinforces the importance of infrastructure strength and operational readiness in enabling post-pandemic recovery. The study concludes that integrated investments in both airline operations and airport infrastructure are critical to building a resilient, efficient, and regionally inclusive aviation ecosystem in India.

A potential limitation of this study is its focus on larger airports, which may not fully capture the unique challenges and resilience of smaller regional airports, particularly those under the UDAN scheme. While the analysis provides valuable insights into the resilience strategies of India's busiest airports, these strategies may not be directly applicable to smaller, lessresourced airports, potentially limiting the broader applicability of the findings across India's airport infrastructure. This gap suggests that the scalability and adaptability of resilience strategies across diverse airport categories warrant further exploration. Additionally, the study primarily relies on quantitative methods (BVAR model), which could be complemented by qualitative approaches to provide a deeper understanding of the operational challenges and strategies employed by stakeholders. Future research could expand on these limitations by investigating the resilience of smaller regional airports, assessing how these airports cope with disruptions and how strategies might be adapted to different airport contexts. Comparative studies between Indian airports and those in other emerging countries could provide valuable insights, particularly in identifying best practices for managing disruptions in similar operational and regulatory contexts. Moreover, integrating qualitative approaches, such as stakeholder interviews, would enhance the understanding of the challenges and opportunities in fostering airport resilience. This mixed-methods approach would complement the quantitative analysis, offering a more holistic view of strategies for enhancing airport performance and sustainability during disruptions.

In conclusion, by categorising resilience into PAX_res and CARGO_res, this study highlights structural patterns that, while grounded in the Indian aviation context, provide insights relevant to other countries with similar operational and regulatory frameworks. The analysis demonstrates that infrastructure strength, effective contingency planning, and operational readiness are critical determinants of airport resilience. Consequently, although the discussion and policy implications are framed within India, the underlying principles identified through this research can inform strategies for enhancing airport performance and resilience in broader aviation markets.

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Ajai Jayathilakan
Name and title of main supervisor:	Dr Thanh Ngo — Senior Lecturer
In which chapter is the manuscript/published work?	Chapter 3

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

The candidate contributed 80% to the manuscript/publication, undertaking the research, analysis, and manuscript preparation with notable independence and initiative. The supervisory team provided methodological guidance, helped refine the analysis, and offered critical feedback during the review process. The work is largely attributable to the candidate, with supervisory input focused on enhancing the quality of the final output.

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Chapter Three – Indian Aviation: Regional connectivity scheme

Preamble

This chapter builds on the analyses presented in Chapters 1 and 2. Chapter 1 examined the determinants of Indian airlines' financial performance, identifying the regional connectivity scheme, UDAN as a significant contributor to improved airline outcomes. Chapter 2 assessed airport resilience through passenger and cargo movements, highlighting the critical role of airport and its infrastructure in sustaining regional aviation operations. Together, these chapters underscore how financial viability and operational robustness are essential foundations for advancing regional connectivity, particularly through the UDAN scheme. Introduced in 2016 under the National Civil Aviation Policy (NCAP), UDAN aimed to enhance connectivity to underserved regions by linking Tier 2 and Tier 3 cities through affordable fares, while supporting regional airports and stimulating local economies. While the scheme initially generated substantial enthusiasm, its performance over time has been mixed. Despite some modest gains in regional traffic and infrastructure development, UDAN has seen a gradual decline in participation from airlines and airports, raising concerns about its sustainability. This chapter shifts focus to the perceptions of key stakeholders—airlines, airport operators, regulators, and travel agents, regarding the challenges facing UDAN's implementation and continuity. A qualitative approach is adopted using the Analytical Hierarchy Process (AHP), a MCDM method that quantifies subjective inputs and ranks complex challenges. By systematically evaluating stakeholder concerns, this study provides insights into the practical obstacles facing UDAN and suggests pathways for more effective and inclusive policy implementation. The findings reinforce the need for stakeholder collaboration to enhance the long-term viability of India's regional connectivity strategy.

Study Three: Stakeholder perspectives on the challenges to successful implementation and continuation of India's regional connectivity scheme- UDAN

Publication status and candidate contribution

This study is currently under review with *Research in Transportation Business and Management* due to the relevance and scope of the research. The PhD candidate is the primary contributor and is listed as the first and corresponding author. The doctoral supervisors, who provided essential guidance, critical feedback, and support throughout the research process, are included as co-authors.

3.0 Abstract

This study investigates the implementation and sustainability challenges of India's RCS, UDAN, through an in-depth analysis of stakeholder perceptions. Despite its founding objective to democratise air travel and stimulate regional development, the scheme has encountered several persistent barriers, including regulatory inefficiencies, infrastructural constraints, limited financial support, and declining stakeholder engagement. Employing the AHP methodology, this study captures and prioritises insights from 31 stakeholders across four key categories: airlines, airports, regulators, and travel agents. The findings reveal that inadequate government subsidies, fragmented policy execution, and poor infrastructure are the most pressing challenges hindering UDAN's effectiveness. By integrating stakeholder perspectives, this research contributes to the growing discourse on regional air connectivity across emerging markets, with India as its focal point. It offers actionable recommendations for enhancing

policy design, fostering institutional coordination, and driving sustainable growth in India's regional aviation sector, which are essential steps toward balanced national development.

3.1 Introduction

Evidence has shown that air transport generates significant benefits to consumers and the wider economy by providing speedy connections between cities and regions through the flow of goods, investments, people, and ideas, which are fundamental drivers of economic growth. (e.g., Bråthen & Halpern, 2012; Das et al., 2020; Fu et al., 2021; Tsui, 2017). According to the Ministry of Civil Aviation (MoCA), India's aviation sector experienced extraordinary growth driven by rapid LCC growths, modern airport developments, FDIs, and advanced information technology interventions (MoCA, 2019a). Private and low-cost airlines have become dominant players in the Indian airline market (Das et al., 2020; Yu et al., 2019), contributing to the rapid increase in both domestic and international passenger traffic in India.

Although the aviation sector in India has been growing and contributing to overall development, these advancements have predominantly focused on Tier 1 cities. The Reserve Bank of India (RBI) categorises urban centres into different tiers based on population. Tier 1 cities, with populations exceeding 100,000, such as Delhi, Mumbai, Bengaluru, Chennai and Kolkata, are major focal points for aviation investments. These cities generate high passenger traffic and revenue due to established infrastructure and economic activities that drive steady demand for air travel. In contrast, Tier 2 cities, with populations between 50,000 and 99,999, are emerging urban centres characterised by diverse economic activities and improved infrastructure. Cities like Pune, Ahmedabad, and Jaipur exemplify this growth, attracting significant investments in sectors such as IT and manufacturing. Meanwhile, Tier 3 cities, with populations ranging from 20,000 to 49,999, are smaller towns that rely heavily on agriculture and local businesses. These cities often face challenges, including inadequate infrastructure and limited economic opportunities. This concentration has created a noticeable gap in regional areas (Tier 2 and Tier 3 regions), resulting in limited or entirely absent airline services, which in turn has hindered regional air connectivity. Despite having 98 operational aerodromes as of 2024, only 57.32% of India's population has access to a domestic aerodrome with regular connections to international airports, compared to a global accessibility average of 74.41% (ICAO, 2024). To address the gap in regional connectivity, the government of India, in collaboration with regulatory bodies, introduced the Route Dispersal Guidelines (RDG) in March 1994 to enhance connectivity to remote areas. Further advancing these efforts, the government launched the NCAP in October 2016 aiming to improve regional air connectivity and make air travel more affordable (see Fageda et al., 2018; Thomas & Jha, 2024). The first UDAN flight, a key outcome of this policy, took off in April 2017. The RCS, commonly known as UDAN, is a pivotal initiative under the NCAP. Table 3.1 provides an overview of the RDG categories before 2016 and the updated classifications following the introduction of the UDAN scheme.

It is often observed that certain regions within a country are overlooked by airlines due to the commercial unviability of operating in these areas, which can be addressed by supporting air connectivity through direct government subsidies or cross-subsidisation (ICAO, 2017). The UDAN scheme was designed to incentivise airlines to offer flight services to smaller and remote regions, improving connectivity and fostering infrastructure development in underserved areas. Through a strategic combination of government subsidies and cross-subsidisation, the initiative aims to make air travel and related infrastructure more accessible across the country.

Table 3. 1

Overview of RDG categories, pre-2017 and post-UDAN

Category	Description (pre-2017)	Description (post-2017)
Category I	12 domestic trunk routes.	Expanded to 20 major domestic trunk routes.
Category II	Routes connecting the Northeast, Jammu and Kashmir, Andaman and Nicobar Islands, Lakshadweep.	Divided into two subcategories: Category II: Flights connecting the Northeast, J&K, Himachal Pradesh, Uttarakhand, Andaman and Nicobar Islands, Lakshadweep. Category IIA: Flights between stations within Category II regions.
Category III	All routes not included in Category I and Category II.	Remained unchanged – includes routes not covered under Category I or Category II.

Source: Das et al. (2020), Sindhwani et al. (2024)

The scheme also seeks to improve access to unserved and underserved airports across India, making air travel more affordable for the general population (PIB, 2022b). By expanding regional connectivity across Indian states and regions, the UDAN scheme aims to stimulate tourism, generate employment, and drive significant growth in the aviation industry (Iyer & Thomas, 2020; MoCA, 2020).

Despite these ambitions, only about 5 percent of the country's population has experienced air travel, a remarkably low figure compared to both developed nations and emerging economies like China and Brazil, with traffic concentrated on trunk routes (e.g., Das et al., 2020; Iyer & Thomas, 2020; Travelli & Kumar, 2023). Since its inception, numerous external and internal factors have influenced the implementation and progress of the scheme, with notable challenges arising, including the unprecedented and formidable COVID-19 pandemic in its later stages. Protracted regulatory clearances, paucity of funding, low demand, insufficient support from state governments, and lack of land tracts with clear titles have variously contributed to the scheme's failure. (e.g., Chandra, 2023; Kaur, 2022; Shroff, 2022; Sindhwani et al., 2024).

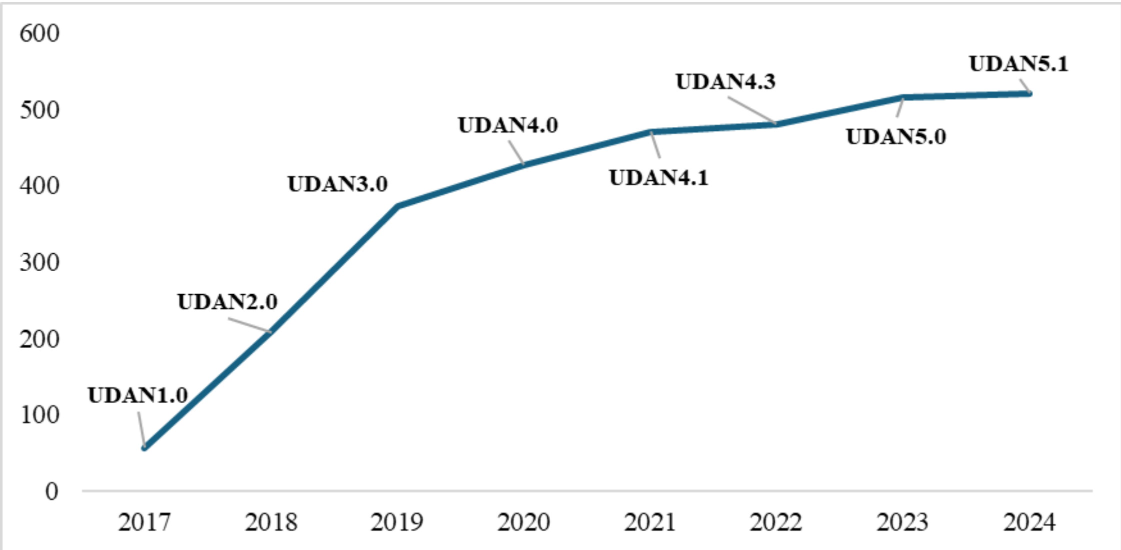
Additionally, Iyer and Thomas (2021) noted a significant research gap in the study of regional airports, despite extensive research on air transport demand in major metropolitan areas. Similarly, Bansal and Sen (2022) point out that the assessment of the Indian airport network, particularly for smaller airports, is insufficiently addressed. In particular, the challenges facing regional aviation in India, especially regarding regional connectivity initiatives, remain underexplored. The UDAN scheme is a market-driven initiative aimed at improving regional connectivity through periodic bidding rounds as airlines assess demand on specific routes and bid for the lowest viability gap funding (VGF). However, as of October 2023, despite five rounds of bidding, many awarded routes have been discontinued by airlines, while air traffic in metropolitan areas continues to grow (Khan, 2023). Furthermore, due to severe financial distress and operational incapacity, many Indian carriers, including the national airline Air India, have restricted and cancelled their flight services to remote states or regions (Iyer & Thomas, 2020). These challenges have significantly impacted the long-term viability of the scheme.

Since its inception, the UDAN scheme has undergone multiple phases, each aimed at expanding regional connectivity and improving operational viability. Launched in 2017, UDAN 1.0 focused on connecting unserved and underserved airports across India, providing airlines with VGF capped at INR 2,500 (USD 29.3) for one-hour flights to ensure affordability. UDAN 2.0 (2018) introduced 73 additional airports and, for the first time and included helipads. UDAN 3.0, launched in collaboration with the Ministry of Tourism (MoT), incorporated tourism routes, seaplanes connecting water aerodromes, and additional routes in the North-East regions, hilly states, and islands, with an emphasis on helicopters and seaplanes.

UDAN 4.0 (2020) further enhanced regional connectivity by linking Kavaratti, Agatti, and Minicoy islands in Lakshadweep[6]. UDAN 4.1 prioritised smaller airports and special helicopter and seaplane routes. UDAN 5.0 shifted focus to larger aircraft (Category-2: 20-80 seats, and Category-3: >80 seats), removing the 600 km distance cap and allowing unrestricted routes between origins and destinations. The subsequent UDAN 5.1 targeted helicopter routes, increasing VGF and reducing airfare caps. UDAN 5.2, currently underway, emphasises connectivity to remote regions and tourism through small aircraft (<20 seats). It introduces operational flexibility, allowing small aircraft operators to manage a maximum of 40% and a minimum of 10% of annually quoted RCS seats in any quarter. Figure 3.1 shows the number of RCS routes awarded as of February 2024.

Figure 3. 1

Number of RCS routes operational in India as of February 2024



Source: MoCA (2023a)

[6] Lakshadweep, India's smallest Union Territory, comprises coral atolls and reef islands in the Arabian Sea. Ecologically sensitive and strategically located, it relies heavily on aviation to overcome logistical challenges and maintain socio-economic connectivity with the mainland, serving a population of approximately 64,500.

Since Study 1 highlights the role of UDAN in boosting airline revenues, this study further explores the challenges faced by the scheme in achieving seamless regional connectivity. It emphasises the necessity of ensuring smooth operations throughout all developmental phases and the importance of a seamless transition between them, especially as the government seeks improvements that not only enhance airline performance but also strengthen the aviation sector as a whole. Therefore, to effectively implement transportation projects like UDAN, policymakers must develop a comprehensive understanding of the subjective nature of decision-making. As this understanding increases the likelihood of selecting solutions that meet the diverse needs of stakeholders, it becomes essential for policymakers to consider their opinions (see Arslan, 2009; Wu et al., 2024). The motivation for this research arises from the challenges and limitations encountered during the implementation and continuation of the UDAN scheme, despite the substantial growth in domestic travel across India. Hence, despite its ambitious goals, the scheme has faced significant obstacles, resulting in underperformance and, in some regions, discontinuation. These challenges underscore the importance of examining the scheme's operational difficulties to identify barriers, learn from past outcomes, and enhance future policy efforts.

In response, this study aims to provide valuable insights to policymakers and stakeholders regarding these impediments to the UDAN scheme. Through a comprehensive pilot study, which involved data collection from relevant stakeholders, the research identifies key challenges. These challenges will then be further analysed using the AHP to offer a well-rounded perspective on enhancing regional connectivity in India. As a MCDM method, AHP offers a systematic approach to prioritising and ranking both major factors and subfactors in complex decision scenarios (Garg & Agrawal, 2023; Mahtani & Garg, 2018). One of the most significant benefits of this method is its ability to incorporate intangibles like experience, subjective preferences, and intuition in a logical and structured manner (Mu & Pereyra-Rojas, 2018). The selected stakeholders encompass airlines, airports, aviation regulators, and travel agents actively involved in or associated with the scheme.

This study seeks to answer the central question: *What are the primary challenges in the implementation and continuation of the UDAN scheme, as perceived by key stakeholders?*

To provide a deeper contextual understanding of the research questions, this study is structured as follows: the next section (3.2) offers a comprehensive review of the relevant literature on regional connectivity schemes. This is followed by a detailed presentation of the research methodology in Section 3.3, including the formulation and development of the model. Subsequent sections analyse and discuss the study's results in Section 3.4, while Section, 3.5 summarises the policy implications, draws conclusions, and suggests potential avenues for future research.

3.2 Literature review

Despite the significant strides made in India's regional aviation sector through initiatives such as the UDAN scheme, the scholarly research on the challenges of the scheme remains limited as the field continues to evolve. This literature review aims to bridge this gap by synthesising existing research and identifying key themes and challenges in the implementation and impact of the scheme on Indian regional air connectivity. The competitiveness of airlines at various geographical levels is intricately linked to their business strategies and home country market structures, forming an interdependent relationship akin to the dynamic between airlines and the broader economy. Market conditions and economic factors both influence and are influenced by airline performance and strategies (Heshmati & Kim, 2016). Meanwhile Salesi et al. (2022) emphasise that aviation subsidy programs remain vulnerable to political influence and potential misuse.

3.2.1 Regional connectivity in India

A study on India's RCS by Iyer and Thomas (2020) noted rapid growth in the civil aviation industry since the introduction of the NCAP in June 2016. Using DEA, the study analysed Indian airports' performance before and after implementing the RCS. While DEA is effective for quantitative efficiency evaluation, it may have missed qualitative insights. Key challenges include inadequate infrastructure, high fares on non-RCS routes, cross-subsidisation issues, previous regional airlines' failures, landing slot problems, VGF issues, regulatory hurdles, and market risks. The success of UDAN, which holds potential for economic growth and regional development, depends on addressing infrastructure, traffic demand, and stakeholder cooperation challenges. The literature review highlighted the importance of stakeholder perceptions in overcoming these challenges. The study also signified the lack of research on air transport in remote regions but noted initial efforts to outline the RCS business model, assess its impact, and identify challenges and opportunities.

The study on profits and revenues of Indian regional airports, based on econometric evidence by Thomas and Jha (2024) provides an in-depth analysis of the financial status of 42 regional airports in India over a five-year period (2014−2019). Using Hausman-Taylor regression, it examines key determinants of airport profitability and revenue, such as passenger traffic, seasonality, and capacity utilisation. The research highlights significant challenges, including low passenger volumes and high operational costs, which impede profitability. Despite these hurdles, the study finds that increased passenger traffic and efficient capacity utilisation can positively impact profitability. While the study's robust dataset and econometric approach offer valuable insights, its limited geographical scope may restrict generalisability. Overall, this research provides a foundation for policy decisions and operational strategies to enhance the financial viability of regional airports, which are crucial for improving connectivity in underserved areas.

The study of Indian RCS by Das et al. (2020) employs a data-driven methodology, analysing characteristics of airports, routes, and regions affected by the program since its inception in 2016. This approach provides an in-depth understanding of the early indicators and future prospects of the RCS, identifying key economic and commercial challenges that need addressing for the program to succeed. One of the strengths of this methodology is its comprehensive data analysis, which allows for detailed insights into the performance and regional imbalances of the scheme. However, a significant weakness is the reliance on early data, which may not fully capture long-term trends and impacts. Additionally, the study highlights the regional imbalance in the performance of the scheme and questions the long-term sustainability of many routes. Despite these strengths, there are gaps in understanding the broader socio-economic impacts of the RCS and its effectiveness in meeting the special needs of remote regions, particularly in the northeast of India.

The research conducted by Das et al. (2022) investigates the factors influencing passenger demand on newly established regional air routes in India, employing a gravity model methodology. The study finds that surface distance positively correlates with passenger demand, indicating higher demand for longer routes. Income per capita at origin and destination locations also positively influences air travel demand, highlighting economic factors' importance. Additionally, the presence of educational hubs significantly impacts passenger demand, emphasising their role in air traffic generation. The study employs multiple regression analysis to explore these factors, addressing multicollinearity through methodological adjustments. Despite its moderate explanatory power, the research contributes valuable insights into regional air travel dynamics in India's growing aviation market. Future research could benefit from longitudinal data to track demand trends over time and explore the influence of policy interventions like Indian regional air connectivity scheme, UDAN.

A research on the UDAN scheme by Sindhwani et al. (2024) examines the viability of regional connectivity by balancing social and economic goals. Using secondary data and qualitative interviews, the research highlights the importance of a hub-and-spoke network over point-to-point connectivity. The study introduces the Viable Hub Location Problem for Regional Connectivity (VHLPRC) model, tested with datasets from the USA and India, revealing both the benefits and hidden costs of regional hubs. Strategic hub placement improves reach but incurs significant expenses and occasional program failures due to low demand. The research underscores the need for resilience and sustainability in network design, suggesting that geographically dispersed hubs can mitigate disruptions. It identifies gaps such as the need for efficient algorithms, environmental sustainability integration, and broader case studies, offering valuable insights for policymakers, academics, and managers in enhancing regional connectivity.

Bansal and Sen (2022) explore the network assessment of Tier 2 Indian cities' airports, focusing on 12 medium-hub international airports to evaluate their performance and potential within India's burgeoning aviation sector. Significantly, the study addresses the underexplored role of Tier 2 city airports in fostering regional development and economic growth, aligning with national policies such as the UDAN scheme aimed at enhancing regional air connectivity. Employing a robust methodology that integrates concentration indices, graph theory-based connectivity measures, and principal component analysis, the research provides a thorough evaluation of airport performance, highlighting insights crucial for prioritising routes and strengthening regional airports. Despite limitations such as a limited timeframe for real-time data collection and a focus solely on Tier 2 cities, the study's findings underscore the importance of regional connectivity in shaping India's aviation landscape and inform strategic policy decisions and infrastructure investments.

A study by Fageda et al. (2019) on air transport connectivity of remote regions in India and the impacts of public policies observed that India's cross-subsidisation between densely and sparsely populated routes requires airlines to balance capacity across both, resulting in similar flight frequencies on protected and unprotected routes. While this policy aims to balance service offerings without relying on public funds, it distorts airline decisions regarding route operations and capacities, reducing efficiency incentives. Protected routes face significant competition from road and rail transport, complicating the policy's effectiveness. Additionally, Fageda et al. (2018) noted that cross-subsidisation among route categories causes airlines to incur losses on Category II airports and necessitates higher fares on Category I routes. The program requires airlines with larger aircraft fleets to operate in Category II routes, creating entry barriers for specialised regional carriers with smaller, more efficient aircraft. Consequently, airlines adopt a cream-skimming strategy, serving primarily state capitals in Category II and III airports, leaving other regions underserved, illustrating the challenges of implementing cross-subsidisation policies effectively.

Iyer and Jain (2020) conducted a critical analysis of the financial sustainability of regional Indian airports by determining the breakeven passenger traffic over a three-year period. Their findings revealed that breakeven passenger traffic decreased from 0.8 million in 2014-15 to 0.6 million in 2016-17, suggesting improved cost efficiency. The study employed linear regression as its methodology. Although the analysis excludes capital expenses and operational efficiency metrics limiting its comprehensiveness, it still provides valuable insights for policymakers and airport managers, especially within the context of the UDAN scheme. This research makes a significant contribution to the literature on regional airport sustainability, underscoring the potential for achieving financial viability in India's regional aviation sector.

While existing studies primarily utilise data-driven methods to evaluate performance, infrastructure challenges, and regional disparities, they often overlook the value of qualitative insights. Quantitative models, such as DEA and regression methodologies, are effective in analysing efficiency and profitability; however, they frequently neglect the nuanced socio-economic impacts of RCS, particularly in underserved regions facing unique challenges. Additionally, current research inadequately addresses the long-term sustainability of RCS and fails to incorporate comprehensive stakeholder perceptions, which are essential for understanding the practical challenges of implementation. This gap underscores the urgent need for integrative research that combines both quantitative and qualitative approaches to thoroughly capture the socio-economic and operational complexities of RCS.

3.2.2 Challenges in regional connectivity

The literature on aviation subsidies, though limited, is critically examined in the study by Gössling et al. (2017), which provides a comprehensive overview of various forms of subsidies within the aviation sector. The study adopts a purposive sampling strategy to identify and categorise existing subsidies along the aviation value chain, with a focus on industrialised countries due to the availability of information. Key findings reveal that substantial subsidies to manufacturers, infrastructure providers, and airlines distort market dynamics, create economic vulnerabilities, and exacerbate climate change by driving rapid capacity expansion in aviation markets. These subsidies also strengthen individual airlines' market positions, causing conflicts with their home countries and raising serious environmental concerns. Moreover, existing studies may overstate the economic benefits of aviation by not fully accounting for the costs associated with subsidies. Despite the study's inability to quantify the total scale of subsidies, it offers valuable insights into the economic interrelationships and potential impacts of these financial aids. The study's methodological strengths lie in its broad categorisation of subsidies and the identification of hidden and indirect subsidies, such as reduced infrastructure fees and tax exemptions.

A critical role of aviation subsidies in enhancing economic and social well-being in the geographically isolated and economically vulnerable South Pacific Region (SPR) was examined by Salesi et al. (2022), highlighting stakeholder perceptions of the impacts of aviation subsidies. The study highlights that aviation subsidies improve airfare affordability, flight accessibility, and service sustainability, thus significantly boosting tourism, a key economic driver for many SPR nations. However, the research also reveals potential drawbacks, including political misuse and negative environmental impacts, underscoring the need for environmentally friendly subsidy frameworks. Despite the pandemic exacerbating financial challenges for the aviation sector, the importance of government support through subsidies remains clear. Through a qualitative approach and stakeholder interviews, the study provides deep insights but also highlights the need for more empirical and quantitative research. This study fills a regional gap in the literature, proposes a framework for effective subsidy programs, and stresses the importance of a collective, region-wide approach to aviation subsidies, especially in the context of post-pandemic recovery.

Santana (2009) investigated the impact of Public Service Obligations (PSOs) in Europe and the Essential Air Service (EAS) Program in the United States on the cost competitiveness of regional airlines. Using panel data spanning 1991 to 2002, the study employed a translog cost function and seemingly unrelated regression (SURE) method to analyse 17 regional airlines. The findings reveal that while European PSOs increase costs for regional carriers, the US EAS program shows no similar adverse effects. This research underscores the necessity for efficient policy frameworks that support regional air connectivity without imposing undue economic burdens on airlines, offering valuable insights for policymakers and stakeholders in the field of air transport economics. However, this is in contrast to the aviation policy in India, where Indian carriers participating in regional connectivity get a VGF from the government through cross subsidisation (Das et al., 2020; Iyer & Thomas, 2020). This study leaves a gap in understanding the long-term effects of PSOs and EAS beyond the studied period, as well as a need for broader geographic comparisons to generalise findings across different regional air transport markets.

The study by Coto-Millán et al. (2014), provides a comprehensive analysis of the technical efficiency of 35 Spanish airports during the challenging economic period from 2009 to 2011. Employing DEA, the research investigates how airport size and the emergence of LCCs affect both technical and scale efficiency. The study identifies significant challenges such as economic downturns negatively impacting airport productivity, particularly through reduced technological advancements. It also highlights how the presence of LCCs influences scale efficiency positively but does not substantially impact pure technical efficiency. The findings align closely with those of Bottasso et al. (2013), Choo and Oum (2013) and De Poret et al. (2015) highlighting the positive impact of LCCs on airports. However, Graham (2013) notes that despite LCCs' transformative influence on the airline-airport relationship and industry dynamics, their enduring long-term effects on airports remain a subject of continued scholarly investigation and discourse. A study by Červinka and Matušková (2018) further suggests that an exclusive focus on LCC traffic may pose economic challenges for regional airports. While LCCs can boost short-term traffic, their contribution to long-term airport sustainability is debatable. This underscores the necessity for regional airports to diversify revenue streams and enhance carrier mix to achieve greater financial resilience. These insights underscore the complexities airports face in balancing economic pressures with operational efficiency, offering valuable lessons for airport managers and policymakers worldwide grappling with similar economic and market challenges.

The study by Donehue and Baker (2012) provides a comprehensive examination of the challenges faced by remote, rural, and regional (RRR) airports in Australia, emphasising high infrastructure and maintenance costs, competitive pressures, and operational sustainability issues. Through a broad survey involving airport managers, regulators, and local councils, the research highlights the essential role of RRR airports in fostering local economic development and ensuring connectivity for dispersed populations. The study's focus on Australia, while providing detailed insights, limits the generalisability of its findings, and potential survey biases present additional limitations. Despite these, the research significantly contributes to understanding the impacts of deregulation and governance changes on regional aviation, offering valuable insights for policymakers. This aligns with Forsyth's (2007) observation that short-term growth in demand leads to more congested terminals and strained facilities, yet most airports manage to avoid significant delays through the use of slot systems, although efficient capacity allocation remains an issue. Long-term capacity expansion efforts are often constrained by environmental and political factors, and investments may not always be cost-effective despite new regulatory frameworks. Therefore, this underscores the need for longitudinal and comparative studies across different countries to better grasp the diverse regulatory impacts on RRR airports. However, a causality analysis study by Baker et al. (2015) on Australian regional airports provides the first empirical evidence of a bi-directional relationship between regional aviation and economic growth in Australia, emphasising the vital need for essential infrastructure to support business operations, tourism, and mobility. A study by Olariaga (2021) on regional connectivity and development in Colombia, aligns with the aforementioned ideology, asserting that regional airports have significantly contributed to the socioeconomic development of the territories. By identifying gaps and providing a robust foundation, this study informs future policy decisions aimed at enhancing the sustainability and effectiveness of regional aviation infrastructure globally.

A study by Ramos-Pérez (2016) on state aid to airlines in Spain from 1996 to 2014 represents a significant advancement in understanding the extent and nature of public subsidies in the Spanish air transport sector. By compiling data from various sources, the research overcomes the challenge of opacity in bilateral agreements and provides a comprehensive view of subsidy distribution across airports and airlines. The study highlights several potential benefits, including increased connectivity and short-term growth, as there was a direct relationship between increased state aid and growth in passenger traffic at subsidised airports. Subsidies also supported regional economic growth and promoted tourism. However, it also underscores that many routes became dependent on subsidies and ceased operations when funding ended, revealing a lack of long-term sustainability. Moreover, the study emphasises the lack of clear objectives, primarily vague tourism goals. While subsidies can offer short-term benefits for regional connectivity, their long-term effectiveness is questioned. This research not only fills gaps in existing literature but also establishes a foundation for future studies examining the economic impacts of airline subsidies in Spain and beyond. Furthermore, there is potential for future research to explore the relationship between subsidies and airport economic performance, as well as to evaluate whether the current subsidised route network optimally contributes to the common good. The findings of this study resonate with those of Chow et al. (2021), who examined airport subsidies in China initiated by the Civil Aviation Administration since 2013. Similarly, they align with a study by Wu et al. (2023) that systematically examined the impact of airport subsidies on the wellbeing of smaller regions in New Zealand. This research underscores that the implementation of airport subsidies significantly increased scheduled flight seat capacity and helped unprofitable regional airports enhance their regional air transport activity. Moreover, the study demonstrates that increases in airport subsidies can stimulate economic growth and employment in the region where the airport is located.

The comprehensive review of transport policies aimed at enhancing air connectivity in remote regions by Fageda et al. (2018) underscores the critical relationship between air connectivity and economic development, particularly in commercially non-viable areas. The study categorises policies into route-based, passenger-based, airline-based, and airport-based types, facilitating a structured analysis of their implementation and global impact. PSOs emerge as the most transparent, offering a clear framework and competitive selection process, albeit with undetermined subsidy amounts, while other policies are less transparent and often lack defined routes and subsidy limits. PSOs exhibit minimal market distortion and strong efficiency and competition incentives, unlike state-owned firms and traffic distribution rules, which can hinder competition. The study’s broad scope and comparative analysis provide valuable insights into best practices and potential pitfalls, despite challenges such as data heterogeneity and the lack of longitudinal analysis. This aligns with Calzada and Fageda (2012), where government-granted price discounts to Spanish-island residents significantly increased route demand. By highlighting gaps and offering a comprehensive comparative analysis, this study emphasises the importance of tailored policies to address specific regional needs, setting the stage for future research on promoting economic growth and social inclusion through effective and sustainable air connectivity initiatives in remote regions.

Apparently, a study by Grubesic et al. (2016) focuses on the EAS program in the United States, examining the spatial and operational efficiencies of the program. This study employs DEA and spatial optimisation models, using inputs like potential demand, distance to hubs, and subsidy allocation, with passenger load factors (PLF) as the output. The research finds that, EAS airports achieved an average operational efficiency of 75.81% and 100% spatial efficiency. However, budget reduction scenarios suggest certain airports could be eliminated with minimal impact on coverage, indicating potential cost savings. Despite the study's strengths, comprehensive efficiency analysis, data-driven insights, and advanced optimisation techniques, it also faces limitations such as reliance on publicly available data and model assumptions that may not always hold. The study highlights the need for further research into the trade-offs between efficiencies, the dynamic nature of EAS, and the local socio-economic contexts of EAS airports.

Evidently, Valido et al. (2014) provide a critical examination of how government subsidies impact air transport in regions with limited competition, as seen in the case of Spain. By developing a robust theoretical model, the research offers nuanced insights into how ad valorem (a type of subsidy that is calculated as a percentage of the ticket price. and specific subsidies affect pricing strategies in monopolistic markets, with a particular focus on the Canary Islands. The study's strength lies in its ability to differentiate between subsidy types and their implications for resident and non-resident passengers, thereby filling a significant gap in the literature. However, the reliance on a theoretical approach, without extensive empirical validation, limits the generalisability of the findings. Despite this, the research makes a substantial contribution to transport economics, offering valuable guidance for policymakers on optimising subsidy strategies to balance territorial equity with market efficiency. Future research is needed to explore alternative subsidy models and validate these findings in broader contexts.

The UDAN scheme has significantly contributed to enhancing airline revenues in India by fostering regional connectivity and expanding market opportunities. As highlighted in prior studies, there is a positive correlation between the scheme and airlines' unit revenue, primarily driven by increased passenger volumes and the introduction of new routes to underserved regions. This increased accessibility not only bolstered passenger numbers but also strengthened airlines' financial performance, mitigating some of the challenges posed by high fuel costs, operational inefficiencies, and intense competition in the aviation sector.

The literature on aviation subsidies and related policies reveals significant gaps that require further investigation on regional connectivity. While existing studies examine the forms and impacts of subsidies, they often focus on specific geographic contexts, limiting insights into long-term effects across diverse aviation markets. Many analyses highlight market distortions and economic vulnerabilities caused by subsidies in developed regions but neglect their implications for regional air connectivity and sustainability in less-studied areas. Additionally, empirical evidence on stakeholder perceptions and the long-term viability of these subsidies is lacking, particularly in under-researched regions. This gap emphasises the need for integrative studies that combine qualitative and quantitative approaches to inform policy frameworks and enhance the sustainability of regional aviation infrastructure globally. Additionally, studies often emphasise the complexity of aligning stakeholder priorities with sustainable aviation goals in regional markets. However, the absence of integrated approaches that assess and prioritise aircraft suitability, efficiency, and environmental impact within regional connectivity frameworks limits comprehensive insights.

3.3 Methodology

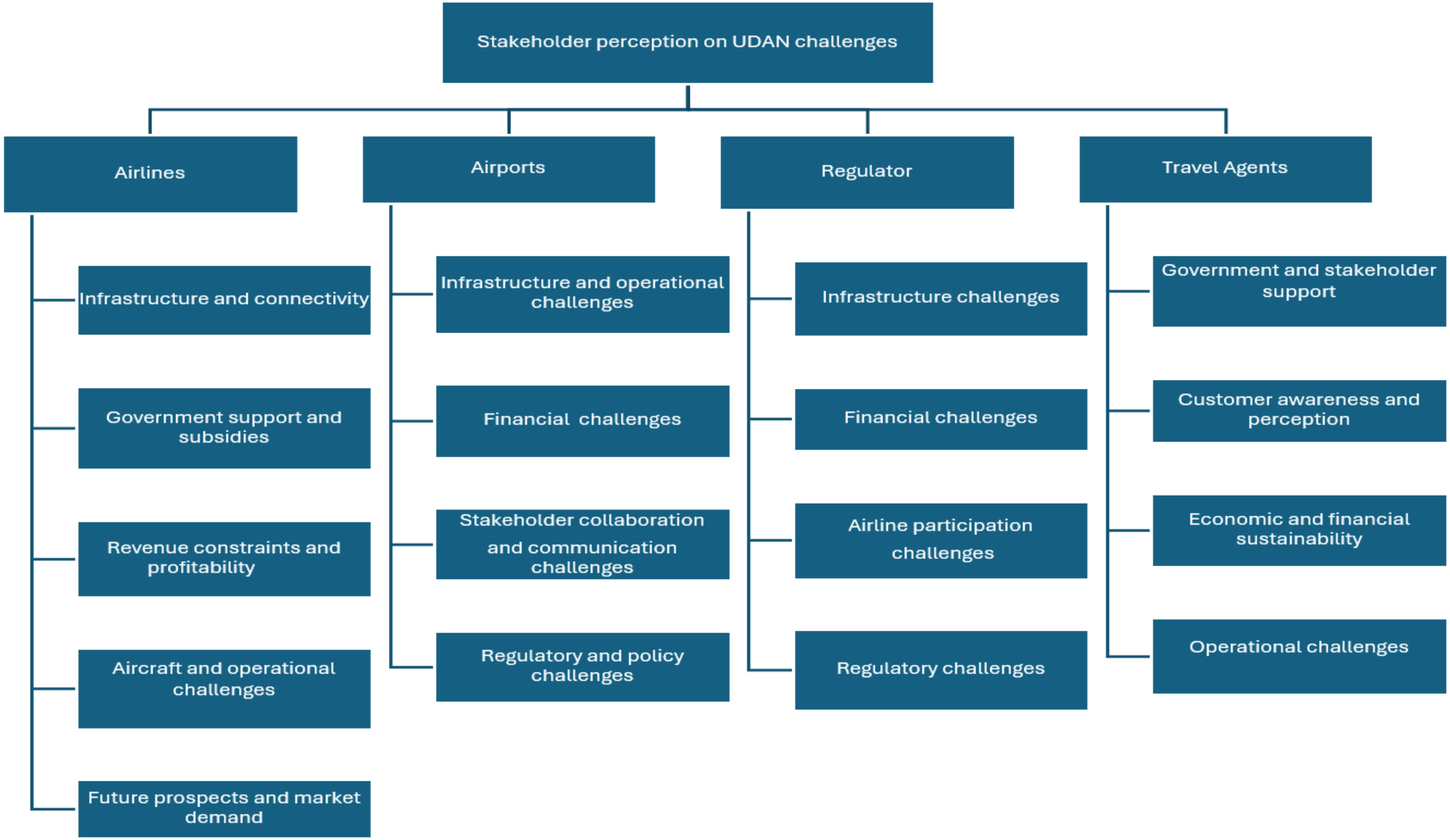
This study aims to identify and analyse the challenges associated with the continuation of the UDAN scheme by examining these issues from the perspectives of key stakeholders, including airports, airlines, regulators, and travel agents. The AHP is ideal for this research, as it allows for a structured, quantitative analysis of these diverse stakeholder perceptions by breaking down complex challenges into a hierarchical framework. By facilitating systematic prioritisation, AHP enables each stakeholder group to evaluate the relative importance of specific challenges affecting the scheme's sustainability. Its effectiveness in managing subjective data from varied sources provides nuanced insights, making AHP highly suitable for understanding the factors critical to the scheme's continuation.

3.3.1 Analytic Hierarchy Process method

AHP methodology, developed by Thomas Saaty in the 1970s, was utilised to systematically capture stakeholders' intuitive judgments in a structured format. A series of structured interviews were conducted with a range of stakeholders, although fewer high-ranking officials participated, providing essential insights into the unique challenges faced by each stakeholder group. Consistent with the approach recommended by Arslan (2009), AHP facilitates the capture of complex decision-making processes through comparative judgments. Although AHP does not prescribe specific outcomes (see Mu & Pereyra-Rojas, 2018) it offers a structured framework to analyse stakeholder preferences based on the relative importance attributed to each identified challenge. Data from these interviews underwent thematic analysis to categorise and map the various challenges associated with the scheme. Building on the interview findings, an online questionnaire was distributed among stakeholders, enabling them to prioritise key challenges and their subcomponents (see, set A–D of Appendix A). This dual approach validated the thematic findings and provided further insights into stakeholder perspectives, underscoring the intricate and multifaceted operational environment underlying UDAN's implementation. Figure 3.2 illustrates the AHP model used to identify primary challenges and their corresponding sub-challenges within the framework of the study.

Figure 3. 2

AHP model illustrating key challenges identified for the study



In AHP, decision-makers conduct pairwise comparisons of elements (such as criteria or alternatives) to determine their relative importance. Saaty (1987) emphasises that pairwise comparisons are fundamental to the application of AHP. These comparisons are recorded in a matrix, with the resulting priorities guiding the decision-making process. The questionnaire followed a one-to-nine-point scale to evaluate the relative importance of challenges, with 1 indicating equal importance, 2-3 representing slightly agreement, and 8-9 denoting extreme agreement (see Saaty & Vargas, 1985), see Table 3.2 below . However, despite its popularity, AHP faces significant challenges in complex, multi-level problems due to the extensive number of pairwise comparison matrices required, making it cumbersome and potentially impractical for large-scale applications (Arslan, 2009; Canco et al., 2021).

Table 3. 2

Fundamental scale of Saaty

Scale	Description
1	Equally important
3	Slightly Agree
5	Strongly important
7	Very strongly agree
9	Extremely agree
2,4,6,8	Intermediate values used when a compromise is needed between two adjacent judgments.

The AHP involves several key equations used to structure decision hierarchies and derive priorities from pairwise comparisons (see Equation (3.1) below).

a. Pairwise comparison matrix: For criteria $C_1, C_2, \ldots, C_n$ construct a pairwise comparison matrix A, where a_{ij} represents the relative importance of criterion C_i and C_j. where i corresponds to the row (base criterion for comparison), and j corresponds to the column (the criterion being compared with i).

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/_{a_{12}} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/_{a_{1n}} & 1/_{a_{22}} & \cdots & 1 \end{bmatrix} \tag{3.1}$$

where, $a_{ij} = \frac{wi}{wj}$, with w_i is the weight of C_i.

b. The comparison matrix is constructed using Equation (3.2) which calculates the number of required pairwise comparisons between n criteria:

$$\text{Number of comparisons} = \frac{n(n-1)}{2} \tag{3.2}$$

where n is the number of criteria (in this study, the challenges)

3.3.2 Eigenvector calculation

In AHP, the priority vector also known as eigenvector plays a crucial role in establishing the relative importance or priority of criteria and alternatives in decision-making processes. In this qualitative study with 31 participants across four stakeholder groups, the eigenvector in AHP represents the underlying priority or significance that participants attribute to each criterion or alternative. After constructing pairwise comparison matrices based on participants' judgments, the eigenvector helps synthesise these judgments into a single priority score. This score reflects the participants’ perception of the importance of different challenges, supporting a structured, quantitative synthesis within the qualitative framework. The most widely used method for estimating a priority vector is the one proposed by Thomas Saaty. This method suggests that the priority vector, representing the relative weights of criteria in a decision matrix, should be derived from the principal eigenvector of Matrix A, which is the vector that remains proportional to itself under a linear transformation (Brunelli, 2015). As seen below, the priority vector can be derived from the following Equation (3.3):

$$A \cdot W = \lambda_{max} \cdot W \qquad (3.3)$$

where W is the eigenvector representing the weights of each criterion and λ_{max} is the maximum eigenvalue of the matrix A.

In the AHP, inconsistencies often emerge due to subjective judgments influenced by cognitive biases or irrational tendencies (e.g., Brunelli, 2015; Hsino & Jasiczak, 2023; Saaty, 2008). Maintaining logical consistency across comparisons is challenging for decision-makers, leading to violations of the consistency condition within the comparison matrix. For example, if criterion A is preferred over B and B is preferred over C, then, logically, A should be preferred over C. Nevertheless, in practice, this transitive consistency is not always maintained, resulting in a consistency ratio that may exceed the acceptable threshold. Such inconsistencies can diminish the reliability of the analysis (Saaty, 2008), underscoring the need to revisit and refine judgments to enhance logical coherence and ensure more robust decision-making. To address these inconsistencies in AHP, the consistency ratio (CR) is calculated to assess the degree of logical coherence in the pairwise comparison matrix as mentioned in Equation (3.5). The CR is calculated by comparing the consistency index (CI) of the matrix with the random index (RI), which reflects the average consistency of randomly generated reciprocal matrices of the same order. The RI values used as benchmarks are selected from Table 11 in Saaty (1990), which reports these indices based on extensive simulations of random matrices. This approach ensures that the RI serves as a threshold indicating the level of inconsistency expected by chance alone in a matrix of given size, as expressed in Equation (3.4) (see Hsino & Jasiczak, 2023; Leal, 2020).

$$\text{Consistency Index (CI)} = \frac{\lambda_{max} - n}{n-1} \tag{3.4}$$

where λ_{max} is the maximum eigen value of the pairwise matrix and n is the number of criteria being compared.

$$\text{Consistency ratio (CR)} = \frac{CI}{RI} \tag{3.5}$$

A CR value of 0.1 or lower is generally considered acceptable, indicating that the judgments are reasonably consistent (Canco et al., 2021; Hsino & Jasiczak, 2023; H. Wu et al., 2024). When the CR exceeds this threshold, it reflects a level of inconsistency that may warrant reconsideration. However, such deviations are not uncommon in complex decision-making contexts, particularly when judgments involve human subjectivity (Canco et al., 2021; Wedley, 1993). In cases where the AHP model is complex or relies heavily on subjective assessments, such as those gathered from human participants, a CR slightly above 0.1 is often tolerated, particularly in social sciences and management studies with small sample sizes (Pauer et al., 2016).

3.3.3 Stakeholder expertise and data collection process

The stakeholder participants in this study were professionals either directly involved with aviation-related entities or closely collaborating with them. A key strength of this study lies in the composition of the AHP participants. While expertise is not always essential for effective decision-making in AHP, given that experience, practice, and mentorship can cultivate expertise over time (Guillén-Mena et al., 2023; Saaty, 1994), this study benefits uniquely from participants who are already seasoned professionals within the aviation industry. This depth of industry-specific knowledge enhances the reliability and insightfulness of the findings. As noted by Lee and Yang (2018), in MCDM studies, the population size is often undefined, and expert groups are usually preferred over general public samples, unlike in political surveys.

Given the diverse nature of aviation stakeholders, the study adopted separate surveys for each stakeholder group rather than using a single questionnaire for all participants. This decision was driven by the fundamental differences in their roles, priorities, and decision-making criteria within the UDAN scheme. The AHP relies on expert judgment to derive relative weights, making it essential to ensure that each group assessed only the criteria relevant to their domain. Generally, airlines focus on operational efficiency and route profitability, airports prioritise infrastructure utilisation and financial sustainability, regulators emphasise policy compliance and safety, while travel agents consider market demand and service accessibility. A single questionnaire would have forced participants to evaluate factors beyond their expertise, potentially leading to response bias and inconsistencies in the pairwise comparisons. By conducting separate surveys, the study ensured that responses were more precise and meaningful, reducing noise in the data while improving the reliability of priority rankings. Additionally, this approach allowed for a more nuanced aggregation of results, enabling a comparative analysis of how priorities differ across stakeholders and highlighting areas of alignment or conflict. Therefore, using separate surveys was not only methodologically appropriate but also necessary to enhance the validity and applicability of the findings.

The survey process began with pilot interviews and discussions held between March and July 2024, helping to identify key challenges. Following this phase, an online bipolar questionnaire was distributed, resulting in 31 complete responses from various stakeholder groups. Incomplete responses were excluded from the analysis. As Bulut et al. (2012) emphasise, expert evaluations are typically prioritised based on their years of industry experience or the consistency of their decision matrices. Our study acknowledges this limitation and accounts for it by carefully considering the analysis and the limited number of participants. The demographic summary of the participants is provided in Table 3.3.

In terms of organisational demographics (see set A–D of Appendix A), the study included eight participants from the airline sector, comprising representatives from Air India (2), SpiceJet (1), IndiGo (4), and other airlines (1). Additionally, seven participants were drawn from various airports, while nine represented regulatory bodies, including the DGCA (2), the MoCA (3), and the Airports Authority of India (AAI) (4). Furthermore, seven participants were travel agents, with three associated with online portals and four representing private operators.

Table 3. 3

Demographic profile of participants

	Airline		Airports		Regulator		Travel agents	
Gender	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Male	7	88%	5	71%	7	78%	3	43%
Female	1	13%	2	29%	1	11%	4	57%
Prefer not to say	0	0%	0	0%	1	11%	0	0%
Age range								
18-25	0	0%	0	0%	0	0%	0	0%
26-35	4	50%	4	57%	2	22%	6	86%
36-45	3	38%	2	29%	7	78%	1	14%
45 or above	1	13%	1	14%	0	0%	0	0%
Years of service								
Less than 3 years	1	13%	0	0%	0	0%	0	0%
3-5 years	4	50%	1	14%	3	33%	4	57%
5-7 years	1	13%	3	43%	3	33%	2	29%
More than 7 years	2	25%	3	43%	3	33%	1	14%

3.4 Results and discussion

A total of 36 responses were collected for the analysis, of which seven were incomplete and subsequently excluded, leaving 31 valid responses for evaluation. Among the 17 challenges assessed across the four stakeholder groups, 14 demonstrated CR values below the acceptable threshold of 0.1, indicating reliable and consistent pairwise comparisons for most criteria (see Appendix D). However, three challenges exceeded the 0.1 threshold, suggesting minor inconsistencies in the responses for these specific criteria. Although these inconsistencies do not undermine the fundamental validity of the analysis, they could have led to minor differences in how challenges were ranked-especially across airlines, airports, and regulatory bodies. As previously discussed (see section 3.2.3), such variations are to be expected in complex decision-making scenarios, particularly when human judgment and subjectivity play a significant role.

Several significant findings warrant highlighting in this discussion, offering valuable perspectives for stakeholders in Indian civil aviation as they develop and refine regional aviation and connectivity strategies. The findings from the AHP analysis are presented in the respective tables within each stakeholder group's section and are categorised and ranked by perceived importance. These rankings are based on survey responses and help prioritise the challenges within the broader context of implementing the UDAN scheme in India’s regional aviation sector.

3.4.1 Airlines

3.4.1.1 Categorisation of main challenges

The primary challenges faced by airlines, as ranked for comparison purposes, are presented in Table 3.4. These challenges are prioritised based on their significance, beginning with infrastructure and connectivity, followed by government support and subsidies, revenue constraints and profitability, aircraft operational challenges, and finally, future prospects and market demand.

The foremost challenge faced by airlines under the UDAN scheme is the inadequacy of supporting infrastructure and connectivity. While the scheme aims to boost regional air travel, airlines often encounter operational difficulties due to insufficient infrastructure, such as limited airport facilities, lack of night-landing capabilities, and inadequate ground support services (e.g., Das et al., 2022; Ohri, 2012; Thakur & Banik, 2018). Furthermore, poor last-mile connectivity deters passenger demand, making it difficult for airlines to achieve sustainable load factors. According to PwC (2022) passenger traffic in smaller towns and cities is projected to grow nearly threefold by 2033, highlighting the critical need for infrastructure development to support airlines in meeting this future demand.

The second challenge pertains to government support and subsidies, which are critical for airlines to ensuring the scheme's sustainability. While the competitive bidding process for route allocations and the provision of VGF initially facilitated airline participation (Chandra, 2023; Thomas et al., 2020), airlines have increasingly expressed concerns about inadequate government support. Additionally, the inconsistent involvement of participating states exacerbates this challenge, raising doubts about the long-term viability of such subsidies. Without sufficient financial backing and cooperative federal support, the sustainability of regional air connectivity remains precarious.

Revenue constraints and profitability, as the third major challenge, further complicate the operational landscape for airlines under the UDAN scheme. Airlines frequently face difficulties in achieving profitability on regional routes due to low passenger loads and capped airfares, which limit their revenue-generating potential. High operational costs including fuel, maintenance, and crew salaries compound the problem, while subsidies often fail to bridge the financial gaps on less popular routes (see Das et al., 2020; Iyer & Thomas, 2020). Additionally, seasonal fluctuations in demand and competition from other modes of transport, such as railways and road transport, erode profitability and threaten the financial sustainability of airlines operating under the scheme.

Aircraft and operational challenges represent the fourth key hurdle in sustaining UDAN operations. The limited and inferior airport infrastructure necessitates the use of smaller aircraft; however, the availability of suitable regional aircraft remains a persistent challenge. The dominance of road and railway networks over regional and intercity travel in India further diminishes the demand for such aircraft (Sharma, 2024). Moreover, the lack of adequate MRO facilities creates additional sustainability challenges, as airlines struggle with maintenance and operational efficiency in the regional aviation sector.

Finally, the future prospects and market demand for the UDAN scheme depend on the readiness of critical support systems, such as air traffic control (ATC), and the ability to attract future investments in regional aviation. While initiatives like allowing 100% FDI in scheduled air transport services aim to encourage growth, airlines have yet to fully capitalise on such policy measures (Chaturvedi & Vatsa, 2021).

Table 3. 4

Pairwise comparison of challenges for airlines category

Main Criteria	CR	Sub-criteria	Weights	Rank
Infrastructure and connectivity	0.060	Development of Airport Infrastructure	0.19	3
		Intermodal connectivity	0.26	2
		Urban integration and accessibility	0.55	1
Government support and subsidies	0.010	Viability gap funding	0.28	3
		State government support	0.36	1
		Financial incentives and concession	0.36	2
Revenue constraints and profitability	0.010	Load factor and seat occupancy	0.57	1
		Pricing strategies	0.22	2
		Cost management	0.21	3
Aircraft and operational challenges	0.120	Availability of suitable aircraft	0.58	1
		Operational costs	0.17	3
		Maintenance, repair and overhauling facility	0.25	2
Future prospects and market demand	0.010	Market demand and growth	0.34	2
		Invest in regional aviation	0.26	3
		Readiness of support system (e.g., ATC)	0.41	1

3.4.1.2 Infrastructure and connectivity

In evaluating the challenges faced by airlines under the UDAN scheme, respondents identified urban integration and accessibility as the foremost concern, followed by intermodal connectivity as the second most significant challenge, and the development of airport infrastructure ranking third. Under the UDAN scheme, airlines face significant challenges, particularly regarding infrastructure and connectivity. The primary concern identified by stakeholders is the integration of regional airports with urban centres, as poor accessibility directly impacts passenger demand. Many Indian regional airports are situated far from major cities, especially in Tier 2 and Tier 3 locations, leading to lower passenger appeal compared to more easily accessible city centres or popular attractions (e.g., Iyer & Jain, 2020; MoCA, 2021; Ohri, 2012). Sun et al. (2024) contends that these optimisations must align with the broader regional transportation infrastructure plan, which primarily emphasises facilitating convenient intra-city transportation for the local population. Additionally, inadequate intermodal connectivity at regional airports under the UDAN scheme poses a significant obstacle. Limited integration with other transportation modes, such as railways and road transport, results in long wait times, missed connections, and passenger dissatisfaction (see Allard & Moura, 2016; De Langen & Sharypova, 2013). Furthermore, the underdeveloped state of many RCS airports in India remains a critical challenge, with deficiencies in runways, terminal capacity, and modern air traffic control systems. Airports operating under visual flight rules (VFR) are particularly vulnerable to weather disruptions, exacerbating operational inefficiencies and costs.

3.4.1.3 Government support and subsidies

The most critical challenges for airlines under the government support and subsidies are ranked as follows: financial incentives, state government support and VGF. Financial incentives under the UDAN scheme aim to make regional routes attractive to airlines but often fall short. Issues such as inadequate incentive levels, complex disbursement processes, and the uneven implementation of tax subsidies and concessions by state governments pose significant challenges (Iyer & Thomas, 2020). While incentives like reduced ATF taxes and minimal to negligible airport charges are beneficial, they frequently fail to offset the high operational costs associated with regional flights**.** State government support is pivotal to UDAN scheme's success, but inconsistent commitment and infrastructure gaps in some states undermine its effectiveness (e.g., Das et al., 2022; Iyer & Thomas, 2020). Bureaucratic hurdles, such as land acquisition challenges without clear rehabilitation policies, further hinder regional airport development (Singh et al., 2015). VGF, while essential for bridging operational cost-revenue gaps on regional routes, faces challenges such as delayed disbursement and reliance on cross-subsidisation from passengers on major domestic routes. This reliance often results in potential overcharging for customers traveling to Tier 1 cities and restricts the intended role of VGF in fostering self-sustaining routes as passenger loads increase (Das et al., 2020; Iyer & Thomas, 2020).

3.4.1.4 Revenue constraints and profitability

The ranking priorities in this category focus on load factor and seat occupancy, followed by pricing strategy, and cost management. According to EconomicTimes (2023), while over 13 million people have benefited from the scheme, the profitability of these regional routes hinges on overcoming the critical challenge of sustaining a viable PLF. Airlines struggle with low demand in Tier 2 and Tier 3 cities, insufficient infrastructure, and limited awareness, leading to financial losses. Seasonal variability and the inherently low passenger volume in remote areas further exacerbate these issues. Routine maintenance, essential for safety, adds to the financial strain, while effective load factor management becomes critical (Ramakrishna & Manjunath, 2018). UDAN's pricing model ensures affordable air travel through subsidised fares but constrains airline revenue with fare caps, making profitability heavily reliant on government VGF. Sindhwani et al. (2024) noted that most routes under UDAN are commercially unviable without policy-driven support, aligning with Das et al. (2020), who observed that while metro routes are more viable and require less subsidy, non-metro routes demand higher financial assistance. High operating costs, the usage of smaller aircraft, and underutilised resources further strain airlines, particularly in economically weaker regions like the North-East, where introducing new routes remains a challenge.

3.4.1.5 Aircraft operational challenges

The primary challenges for airlines under the UDAN scheme, ranked in order of importance, are the availability of suitable aircraft, MRO facilities, and operational costs. As Deshpande (2019) highlights, the success of airlines within the scheme hinges on utilising regional transport aircraft (RTA) or smaller aircraft. These are essential for frequent trips to smaller cities due to their lower fuel consumption and suitability for shorter runways. However, regional carriers face challenges such as high acquisition costs and a limited selection of aircraft models. Additionally, new entrant airlines experience delays in obtaining the Scheduled Commuter Operator (SCO) permit, further complicating their operations (Das et al., 2020; MoCA, 2024b). The process of expanding aircraft capacity, particularly for regional operations, is cumbersome due to acquisition challenges and a shortage of trained personnel. Compounding these issues is the market's preference for larger narrow-body aircraft in India, which restricts the availability of regional aircraft and hampers UDAN's scalability and sustainability. Additionally, MRO services are concentrated in metro cities, causing inefficiencies and higher costs due to long-distance aircraft transport for maintenance (MoCA, 2019b). Despite goods and services tax (GST) reductions, the lack of local infrastructure remains a barrier in UDAN's success. Additionally, operational costs, including fuel, ground-handling fees, and maintenance, strain participating airlines with fluctuating fuel prices and low seat occupancy worsening profitability. While 28 seaplane and 115 helicopter RCS routes have been awarded (see MoCA, 2024a), their viability and impact, particularly for tourism in regions like Andaman and Nicobar Islands, require further study.

3.4.1.6 Future prospects and market demand

Among the challenges related to future prospects and market demand for airlines, the readiness of support systems, such as ATC, is the highest priority. This is followed by market demand and growth, while investment in regional aviation is ranked as the least critical. As noted by

AAI (2018), the development of regional airports will markedly shift the distribution of peak traffic loads. The effectiveness of UDAN heavily relies on the adequacy of infrastructure and outdated systems and limited capacity at regional airports can hinder efficiency and safety (AAI, 2023; Chaturvedi & Vatsa, 2021; S. Jain et al., 2021). Donehue and Baker (2012) presents a similar argument, noting that the infrastructure of remote, rural, and regional (RRR) airports, particularly runways, terminal buildings, lighting, safety, and navigational equipment, requires ongoing and costly updates, emphasising the readiness of support system. Market demand and growth are crucial for UDAN's success, but fluctuating passenger numbers and economic conditions pose challenges. Despite growth potential, some routes face low demand, impacting financial viability (see Iyer & Thomas, 2020; Khan, 2023). While India's regional aviation market includes a significant share of turboprops, as highlighted by Ryerson and Ge (2014), initiatives like Pawan Hans[7] have limitations due to their small seating capacities (MoCA, 2020). From an investment perspective, regional aviation remains an important enabler; however, limited funding for fleet expansion, the high costs of operating on regional routes, and the shortage of trained personnel continue to affect the long-term viability of regional connectivity initiatives.

3.4.1.7 Overall ranking of sub-challenges

In this study, the terms global weight and overall weight are used interchangeably. The inclusion of global weights and rankings (see Appendix D) provides a comparative framework for assessing the relative importance of challenges within each stakeholder group, as suggested by Mahtani and Garg (2018), particularly in the airline sector. While local weights reflect the specific priorities and challenges unique to each stakeholder group—such as airlines, airports, regulators, and travel agents—global weights are used exclusively to compare sub-challenges

[7] Pawan Hans, India's national helicopter operator, manages one of the largest fleets of Airbus-manufactured Dauphin helicopters. As the flagship helicopter service provider for the Indian government, it operates around 43 helicopters, making it one of the largest helicopter companies in South Asia.

within the airline stakeholder group, rather than across all stakeholder groups (see Table 3.5). In this context, the global weight is calculated as the product of the local weight of the sub-challenge and the weight of the main challenge (Canco et al., 2021; Keshavarz-Ghorabaee et al., 2018), as seen in Equation (3.6):

$$\text{Global Weight} = \text{Weight of main challenge} \times \text{Local weight of sub-challenge} \quad (3.6)$$

This approach enables a nuanced analysis of how various challenges are perceived internally, highlighting internal variations and priority differences among airline stakeholders. By incorporating both local and global weights, the study ensures a more comprehensive evaluation of stakeholder perceptions, facilitating a clearer understanding of the factors influencing the implementation and continuation of the UDAN scheme. This refined analysis enhances the depth of findings, offering valuable insights for policymakers at both regional and national levels.

Table 3. 5

Comparison of local and overall weights for airline sub-challenges

Sub-criteria	**Local weight**	**Local rank**	**Overall weight**	**Overall rank**
Urban integration and accessibility	0.549	1	0.157	1
Load factor and seat occupancy	0.572	1	0.122	2
Financial incentives and concession	0.362	2	0.094	3
State government support	0.356	1	0.092	4
Availability of Suitable aircraft	0.581	1	0.078	5
Intermodal connectivity	0.259	2	0.074	6
Viability GAP funding	0.282	3	0.073	7

Development of airport infrastructure	0.191	3	0.055	8
Pricing strategies	0.215	2	0.046	9
Cost management	0.212	3	0.045	10
Readiness of support system (e.g., ATC)	0.408	1	0.044	11
Market demand and growth	0.336	2	0.036	12
Maintenance, repair and overhauling facility	0.245	2	0.033	13
Invest in regional aviation	0.256	3	0.027	14
Operational costs	0.174	3	0.023	15

From an airline's perspective, infrastructure, revenue constraints, and government support are pivotal for sustaining operations under the UDAN scheme. Urban integration and accessibility (Rank 1) is the foremost concern, as seamless connectivity between airports and urban centres directly impacts passenger demand. Similarly, load factor and seat occupancy (Rank 2) highlight airlines' dependency on achieving sufficient occupancy rates to maintain profitability, emphasising the need for robust passenger demand. Financial incentives and concessions (Rank 3) and state government support (Rank 4) reflect airlines' reliance on subsidies and policy-driven assistance to offset operational costs. Operational challenges and infrastructure development also significantly impact airline performance. Availability of suitable aircraft (Rank 5) is a key concern, as the limited availability of small aircraft restricts route expansion. Additionally, intermodal connectivity (Rank 6) ensures smoother passenger movement across different transport modes, directly influencing demand. VGF (Rank 7) remains critical for airlines to sustain operations beyond the initial subsidised phase, reducing financial vulnerability. The development of airport infrastructure (Rank 8) is equally crucial, as inadequate facilities limit service efficiency and expansion.

Revenue constraints and profitability continue to challenge airline sustainability. Pricing strategies (Rank 9) and cost management (Rank 10) underscore the delicate balance between competitive pricing and financial viability in regional routes. Additionally, readiness of support systems like ATC (Rank 11) and market demand and growth (Rank 12) highlight the need for efficient regulatory infrastructure and sustainable demand growth to ensure airline profitability. Lastly, maintenance and long-term investment in regional aviation remain crucial for airline resilience. MRO facilities (Rank 13) affect operational efficiency, while investments in regional aviation (Rank 14) determine long-term sustainability. Operational costs (Rank 15) reflect persistent financial challenges that airlines face, further reinforcing the necessity of continued government intervention and strategic cost management.

In summary, airlines prioritise passenger demand, financial incentives, infrastructure development, and operational efficiency as key determinants of success in the UDAN scheme. Addressing these concerns through policy support, targeted subsidies, and infrastructure investments will be crucial to ensuring airline sustainability in regional aviation.

3.4.2 Airports

3.4.2.1 Categorisation of main challenges

The primary challenges faced by airports, ranked in order of significance, are presented in Table 3.6 as shown below. Starting with infrastructure and operational challenges, followed by financial challenges, stakeholder collaboration and communication issues, and finally, regulatory and policy challenges.

Table 3. 6

Pairwise comparison of challenges for airports category

Main Criteria	CR	Sub criteria	Weights	Rank
Infrastructure and operational challenges	0.030	Inadequate infrastructure and connectivity	0.67	1
		Environmental and land acquisition issues	0.15	3
		Security and safety concerns	0.18	2
Financial challenges	0.060	Lack of revenue from RCS flights	0.60	1
		High operational cost	0.11	3
		Insufficient subsidies and support	0.29	2
Stakeholder collaboration and communication challenges	0.110	Poor stakeholder cooperation	0.31	2
		Lack of clear communication and transparency	0.09	3
		Urban integration and accessibility (last mile connectivity etc.)	0.60	1
Regulatory and policy challenges	0.010	Bureaucratic hurdles and unclear responsibilities	0.52	1
		Insufficient support for airports	0.31	2
		Regulatory constraints affecting operations	0.17	3

Airports face a range of complex challenges that significantly affect their operational efficiency and long-term sustainability. Infrastructure and operational limitations are particularly pressing, as many airports, especially in regional areas, contend with inadequate facilities, outdated equipment, and constrained capacity to meet increasing passenger and cargo demands. These issues are compounded by financial challenges, including insufficient funding, escalating operating costs, and a reliance on subsidies to maintain viability. Furthermore, ineffective stakeholder collaboration exacerbates operational inefficiencies, with misaligned objectives, inadequate coordination, and fragmented decision-making among airlines, regulators, and other entities hindering seamless operations. Regulatory and policy constraints further complicate the landscape, as rigid, inconsistent, or overly complex frameworks impede decision-making processes and stifle opportunities for innovation and sectoral growth.

3.4.2.2 Infrastructure and operational challenges

While in airports, the foremost challenges include inadequate infrastructure and connectivity, followed by secondary challenges such as security and safety concerns, with environmental and land acquisition issues ranking third. Many regional airports lack essential facilities, including modern terminals, sufficient runway length, and advanced air traffic control systems and operations are based on VFR (Das et al., 2020; Iyer & Thomas, 2020). The absence of night landing capabilities and poor connectivity to major transportation networks further exacerbate operational inefficiencies. These limitations restrict the ability to handle increased traffic and discourage airlines from operating more frequent flights, impacting the scheme's success. The scheme was allocated INR 4,500 crore (approximately $56.25 million) for airport revivals, with 46 redeveloped by the AAI and others by state governments and public service undertakings (PSUs) (Chandra, 2023). To date, INR3,490 crore (about $43.625 million) has been spent, with an additional INR1,000 crore (around $12.5 million) approved for the next three years. Security and safety challenges persist, particularly at regional airports that lack modern equipment and trained personnel, making compliance with safety regulations difficult in older infrastructure (ICAO, 2012). Environmental and land acquisition issues also hinder airport expansion, with conflicts, legal delays (Omuya & Nkolo, 2023), and ecological sensitivities increasing costs and timelines (Arushi & Drews, 2011; ICAO, 2012).

3.4.2.3 Financial challenges

For airports, the key financial challenges under the UDAN scheme, in order of priority are insufficient revenue from RCS flights, inadequate subsidies, and high operational costs for the participating airports. The challenge of lack of revenue from RCS flights is a primary concern for most regional airports. These airports struggle with low passenger volumes, limited commercial traffic, and low flight frequencies, resulting in inadequate income from passenger fees, landing and parking charges, and other services. As these airports serve smaller towns with lower demand for air travel, their occupancy rates are often insufficient to generate sustainable revenue (see Iyer & Jain, 2020; Thomas & Jha, 2024). The lack of non-aeronautical revenue sources, such as retail and advertising, further worsens their financial difficulties, making it impractical to rely on alternative income streams due to the limited commercial activity at these locations. Insufficient subsidies and support under the UDAN scheme further complicate matters, as regional airports rely heavily on government subsidies (Das et al., 2022), which are not a sustainable long-term solution. Despite these subsidies, high operational costs, including security, fire protection, and maintenance, remain a challenge. Seasonal demand fluctuations exacerbate these costs, as airports must maintain the same high operational standards during low traffic periods, making long-term viability dependent on consistent government support.

3.4.2.4 Stakeholder collaboration and communication challenges

The highest-priority challenges in stakeholder collaboration and communication challenges were urban integration and accessibility, poor stakeholder cooperation, and a lack of clear communication and transparency. Similar to the challenges for airlines in infrastructure and connectivity, many regional airports are situated on city outskirts or in remote areas, complicating passenger access. Often, these airports lack integration with urban infrastructure, such as road networks and public transportation, which affects passenger convenience, utilisation rates, and scheme performance (e.g., Gaurav, 2023; MoCA, 2023; NTDPC, 2014). Insufficient urban planning intensifies these issues, leading to operational inefficiencies and passenger dissatisfaction. Effective stakeholder collaboration, including airport operators, airlines, government bodies, and local communities, is critical for the success of the UDAN scheme. However, poor coordination often leads to project delays, misaligned objectives, and operational inefficiencies. A major challenge for regional airports is the lack of transparent communication, which results in misunderstandings, misaligned expectations, and diminished accountability. This issue is worsened by the complex regulatory environment, increasing the likelihood of delays, cost overruns, and operational inefficiencies (WEF, 2014).

3.4.2.5 Regulatory and policy challenges

Under the UDAN scheme, airports face significant regulatory and policy challenges, ranked as follows: bureaucratic hurdles and unclear responsibilities at the forefront, followed by insufficient support, and finally, stringent regulatory constraints impacting operations. Regulatory constraints often hinder the smooth functioning of airports, particularly within a complex bureaucratic landscape (Jain et al., 2021). For instance, airports frequently experience delays in securing approvals due to the involvement of multiple government agencies with divergent regulations and procedures (Iyer & Thomas, 2020). Regulatory measures aim to promote economic activities in regional and remote areas (Mishra et al., 2021); however, unclear agency responsibilities result in confusion and inefficiency. This ambiguity often leads to project delays and increased costs, as issues are repeatedly transferred between agencies without effective resolution. Airports under the UDAN scheme also face insufficient regulatory and financial support, with limited funding hampering infrastructure upgrades, operational maintenance, and compliance with safety and security standards. This resource scarcity limits airport efficiency and challenges the sustainability of airline services. Additionally, regulatory constraints like environmental assessments and safety protocols increase costs for smaller airports, complicating their operations under the UDAN scheme (MoCA, 2021a).

3.4.2.6 Overall ranking of sub-challenges

The local and global weights for key challenges are presented below in Table 3.7.

Table 3. 7

Comparison of local and overall weights for airport sub-challenges

Sub-criteria	Local weight	Local rank	Overall weight	Overall rank
Inadequate infrastructure and connectivity	0.477	1	0.319	1
Lack of revenue from RCS flights	0.311	1	0.187	2
Insufficient subsidies and support	0.311	2	0.090	3
Security and safety concerns	0.477	2	0.087	4
Urban integration and accessibility (last mile connectivity etc.)	0.120	1	0.072	5
Environmental and land acquisition issues	0.477	3	0.071	6
Bureaucratic hurdles and unclear responsibilities	0.092	1	0.048	7

Poor stakeholder cooperation	0.120	2	0.038	8
High operational cost	0.311	3	0.035	9
Insufficient support for airports	0.092	2	0.029	10
Regulatory constraints affecting operations	0.092	3	0.015	11
Lack of clear communication and transparency	0.120	3	0.011	12

From an airport's perspective, inadequate infrastructure and connectivity rank as the most critical challenge (Rank 1). The success of UDAN largely depends on an airport's ability to handle increased flight operations, which is constrained by limited terminal capacity, inadequate runway facilities, and poor multimodal transport integration. Financial sustainability follows closely, with the lack of revenue from RCS flights (Rank 2) and insufficient subsidies (Rank 3) posing significant risks to operational viability. Many UDAN airports struggle with low passenger volumes, making it difficult to recover costs without sustained financial support. Security and safety concerns (Rank 4) further complicate operations, especially in smaller regional airports, where resource constraints limit compliance with stringent aviation safety standards.

Beyond infrastructure and financial concerns, urban integration and last-mile connectivity (Rank 5) highlight the difficulty of ensuring seamless passenger movement from airports to urban centres. Environmental and land acquisition issues (Rank 6) also pose regulatory and operational challenges, slowing airport expansion and new infrastructure development. Bureaucratic hurdles and unclear responsibilities (Rank 7) within policy frameworks further delay project approvals, impacting timely execution of UDAN objectives. Poor stakeholder cooperation (Rank 8) limits coordination between airlines, regulatory bodies, and airport authorities, hindering efficient route planning and service sustainability. High operational costs (Rank 9) add another layer of financial strain, particularly for airports struggling with low passenger throughput. Insufficient support for airports (Rank 10) underscores the gaps in regulatory backing, including inadequate maintenance grants and policy inconsistencies affecting long-term sustainability. Regulatory constraints (Rank 11), such as restrictions on aircraft types and licensing requirements, further restrict operational flexibility. Lastly, lack of clear communication and transparency (Rank 12) among stakeholders exacerbates coordination issues, delaying crucial policy interventions and infrastructure investments needed to enhance regional connectivity under UDAN.

In summary, the most pressing challenge is inadequate infrastructure and connectivity, which directly affects operational capacity and limits the scheme's success. Financial sustainability remains a significant concern, with low passenger volumes and insufficient subsidies threatening viability. Security and regulatory constraints further complicate operations, especially for smaller airports. Beyond these core issues, urban integration, environmental challenges, and bureaucratic inefficiencies hinder seamless connectivity and infrastructure expansion. Poor stakeholder cooperation and high operational costs exacerbate financial pressures, while inconsistent regulatory support and communication gaps further impede long-term sustainability. Addressing these challenges requires a holistic approach, balancing infrastructure upgrades, financial incentives, and coordinated policy interventions to ensure the continued success of regional connectivity under UDAN.

3.4.3 Regulator

3.4.3.1 Main challenges for stakeholders

The challenges, ranked in order of priority, include infrastructure challenges, financial challenges, airline participation challenges, and regulatory challenges. From the regulators' perspective, the challenges in implementing the UDAN scheme are multifaceted, with infrastructure readiness being the most critical. Delays in land acquisition and inadequate airport infrastructure significantly hinder the commencement of operations. Financial challenges, including the lack of revenue generation for regional airports and concerns over the sustainability of VGF for airlines, worsen the issue. Airline discontinuation further undermines the scheme's objective of enhancing regional connectivity. Additionally, the absence of a well-developed ecosystem for smaller aircraft operations, including gaps in MRO, poses regulatory challenges. These issues collectively threaten the scheme's success and require focused efforts to ensure its sustainability and socio-economic impact. The ranked challenges are summarised in Table 3.8.

Table 3. 8

Pairwise comparison of challenges for regulators category

Main Criteria	CR	Sub-criteria	Weights	Rank
Infrastructure challenges	0.025	Slow-paced infrastructure creation	0.32	2
		Land acquisition and regulatory compliance issues	0.13	3
		State government's limitations in regulatory compliance	0.09	4
		Challenges in asset readiness for operations	0.47	1
Financial challenges	0.009	Absence of revenue generation	0.51	1
		High ATC costs for airport operators	0.14	3
		Monopoly of air traffic management by AAI	0.08	4
		Operational challenges without commercial flights	0.27	2

Airline participation challenges	0.107	Competition on assigned routes	0.18	3
		Continuation of operations beyond initial three-year period	0.33	2
		Maturity of routes into commercial viability	0.13	4
		Airlines opting out and reasons for discontinuation	0.36	1
Regulatory challenges	0.073	Pace of infrastructure creation (CAPEX)	0.22	2
		Role of regulators in addressing challenges	0.11	3
		Lack of a well-developed ecosystem for small airlines	0.60	1
		Policy uncertainty and regulatory clarity	0.07	4

3.4.3.2 Infrastructure challenges

Stakeholders including MoCA, DGCA, and AAI point to key challenges like asset readiness, delays in infrastructure development, land acquisition, and regulatory compliance, hindering the successful implementation of the UDAN scheme. Ensuring asset readiness at remote airports is a critical issue. Many airports lack essential facilities like runways, taxiways, and terminals, as noted by Jain et al. (2021), delaying the commencement of operations and hindering the scheme's objectives. The situation is compounded by the need for specialised equipment and adherence to ICAO safety standards (ICAO, 2024). This challenge is especially severe in smaller airports, where financial limitations and bureaucratic delays slow down project execution (see AAI, 2021;AAI, 2023). Such delays also raise operational costs for airlines due to infrastructure uncertainty. Land acquisition remains a major bottleneck, often delayed by legal disputes, local resistance, and overlapping regulatory jurisdictions (CPR, 2019). State governments, key to acquisition and infrastructure development, face capacity limitations, struggling with stringent regulatory standards and causing delays in clearances and inconsistent enforcement of safety and environmental norms.

3.4.3.3 Financial challenges

From the perspective of the DGCA and other regulators, financial challenges are critical to ensuring the viability of airlines and airports under the UDAN Scheme. The challenges ranked in order under financial challenges are absence of revenue generation, operational challenges without commercial flights, high ATC costs for airport operators and finally monopoly of air traffic management by AAI. A primary issue is the lack of consistent revenue generation, particularly for airports in remote areas with low passenger traffic. These airports face underutilisation of resources, compounded by the absence of cargo operations and limited ancillary services. This leads to a significant financial burden on operators. While the VGF provides some support, it remains inadequate to cover long-term operational costs, making sustainable operations difficult for both airlines and airports (MoCA, 2019b, 2021b). Operational challenges include irregular flights due to seasonal demand fluctuations, increasing costs without proportional revenue. Smaller airports, unable to accommodate larger aircraft, face reduced capacity. High ATC service costs, managed by the AAI, strain finances for UDAN airports, which must maintain services regardless of flight frequency. The AAI's monopoly inflates operational costs, limits flexibility, and passes inefficiencies to airlines and passengers. Compliance with international safety standards further adds financial burden through investments in technology and training.

3.4.3.4 Airline participation challenges

Under this challenge, the primary concern is that airlines are opting out and discontinuing their participation in the scheme. Following this, sustaining operations beyond the initial three-year period becomes a key issue. Additionally, managing competition on assigned routes and achieving the commercial viability of these routes over time are significant factors that need to be addressed. From the DGCA's perspective, a key financial challenge for airlines under the scheme is the high cost of operating in less commercially viable regions. Despite VGF, airlines often withdraw due to unsustainable losses, where fuel, maintenance, and low passenger loads outweigh subsidies. Operational inefficiencies and limited economies of scale further strain airlines, forcing them to discontinue certain routes. The DGCA monitors these trends and ensures compliance with the scheme while balancing economic sustainability. Airlines face challenges in maintaining operations once the initial three-year VGF period ends, as many routes fail to achieve commercial viability without continued subsidies (Thomas & Jha, 2024). Competition for RCS routes can introduce financial risks, with underbidding leading to unsustainable operations (Khan, 2023; PIB, 2022b). Route maturity, dependent on sustained passenger growth, better infrastructure, and marketing, often struggles due to low demand and high operating costs.

3.4.3.5 Regulatory challenges

While the DGCA's role encompasses streamlining regulatory processes, enhancing access to essential services, and fostering supportive policies for small airlines, the primary regulatory challenge under the UDAN scheme lies in the absence of a well-developed ecosystem for these carriers (AAI, 2022; Gaurav, 2023). Small airlines face significant difficulties due to limited access to financing, skilled labour, and MRO facilities. These challenges are further compounded by India’s fragmented aviation support infrastructure, resulting in higher operational costs and reduced profitability for these airlines. Additionally, the lag in capital expenditure (CAPEX), which results in the slow pace of infrastructure development at smaller airports, particularly in upgrading runways, terminals, and safety equipment is another concern. This delays operational efficiency and safety, impacting the profitability of regional services. Similar risks are seen in the Indian sector, as exemplified by Alitalia's failure due to political ambiguity and insufficient infrastructure investments (see Beria et al., 2011). Policy uncertainty and regulatory ambiguity further hinder the scheme’s success.

3.4.3.6 Overall ranking of sub challenges

From a regulatory standpoint (see Table 3.9), financial viability is the foremost concern for the sustainability of the UDAN scheme. The absence of revenue generation (Rank 1) underscores the fundamental challenge regional airports face in achieving self-sufficiency, making them dependent on government subsidies.

Table 3. 9

Comparison of local and overall weights for regulator sub-challenges

Sub-criteria	Local weight	Local rank	Overall weight	Overall rank
Challenges in asset readiness for operations	0.433	1	0.203	1
Absence of revenue generation	0.283	1	0.144	2
Slow-paced infrastructure creation	0.433	2	0.137	3
Airlines opting out and reasons for discontinuation	0.235	1	0.086	4
Operational challenges without commercial flights	0.283	2	0.078	5
Continuation of operations beyond initial three-year period	0.235	2	0.077	6
Land acquisition and regulatory compliance issues	0.433	3	0.054	7
Competition on assigned routes	0.235	3	0.042	8

High ATC costs for Airport operators	0.283	3	0.039	9
State government's limitations in regulatory compliance	0.433	4	0.039	10
Maturity of routes into commercial viability	0.235	4	0.031	11
Lack of a well-developed ecosystem for small airlines	0.05	1	0.030	12
Monopoly of air traffic management by AAI	0.283	4	0.022	13
Pace of infrastructure creation (CAPEX)	0.05	2	0.011	14
Role of regulators in addressing challenges	0.05	3	0.006	15
Policy uncertainty and regulatory clarity	0.05	4	0.004	16

Persistent regulatory, financial, and operational challenges continue to impede the successful implementation and long-term viability of UDAN. At the forefront is the challenge of asset readiness for operations (Rank 1), which reflects significant delays in making airports fully functional after infrastructure investment. These readiness issues diminish the effectiveness of the scheme, as many facilities remain underutilised or non-operational due to incomplete assets and lack of preparedness. Equally critical is the absence of revenue generation (Rank 2), which threatens the financial sustainability of both airlines and airports. With limited passenger footfall and insufficient commercial activity, regional airports struggle to become financially independent. These financial strains are compounded by the slow-paced infrastructure creation (Rank 3), where the lag in physical development fails to align with the urgency of expanding regional connectivity. The opting out of airlines and their reasons for discontinuation (Rank 4) further underscore the unsustainability of operations once the three-year subsidy period ends. Many airlines find it difficult to maintain services without continued financial support, often citing insufficient demand and high operating costs. This directly contributes to operational challenges in the absence of commercial flights (Rank 5). Despite significant infrastructural investments, the lack of airline interest in operating from these airports leaves facilities idle and communities underserved. The continuation of operations beyond the initial three-year period (Rank 6) is another pressing concern, indicating the scheme's struggle to convert subsidized routes into commercially viable ones. This transitional failure raises doubts about the long-term resilience of the network.

Land acquisition and regulatory compliance issues (Rank 7) also pose considerable barriers to timely airport development. Bureaucratic delays and fragmented regulatory oversight hamper progress in expanding airport capacity and establishing new facilities. The competition on assigned routes (Rank 8) introduces further complexity. Limited participation and market distortions discourage newer entrants and reduce the effectiveness of competition, thereby impacting service quality and pricing. The high ATC costs borne by airport operators (Rank 9) add another layer of financial pressure, particularly affecting smaller regional airports with limited revenue streams. Additionally, state governments' limitations in regulatory compliance (Rank 10) reflect inconsistent implementation and enforcement across regions, further stalling progress in expanding connectivity.

Another notable challenge is the maturity of routes into commercial viability (Rank 11). Many routes have failed to generate sustainable passenger demand, forcing airlines to withdraw even after initial subsidies. A lack of a well-developed ecosystem for small airlines (Rank 12) exacerbates these issues. Structural weaknesses such as inadequate maintenance facilities, training institutions, and supply chain support restrict the growth of smaller carriers, who are essential for last-mile connectivity. The monopoly of air traffic management by the AAI (Rank 13) contributes to operational inefficiencies and elevated costs. This centralization limits flexibility and responsiveness in managing regional air traffic demands. Compounding the issue is the slow pace of CAPEX infrastructure creation (Rank 14), which further delays the operationalization of airports and hinders long-term planning. The regulators' role in addressing these challenges (Rank 15) has also been limited, often reactive rather than proactive. Inconsistent policy implementation and limited engagement with stakeholders result in misaligned priorities and fragmented solutions. Lastly, policy uncertainty and lack of regulatory clarity (Rank 16) continue to deter long-term investment by both public and private stakeholders. The absence of stable and transparent regulatory frameworks undermines confidence in the future of regional aviation.

In summary, the success of the UDAN scheme is constrained by delays in operational readiness, infrastructure creation, financial sustainability, and regulatory inefficiencies. Addressing these interconnected challenges will require coordinated policy reforms, expedited infrastructure development, and targeted financial strategies to ensure the long-term viability of regional air connectivity in India.

3.4.4 Travel agents

3.4.4.1 Main challenges for travel agents

Among the challenges identified by travel agents, the most significant priority is securing government and stakeholder support. This is followed by customer awareness and perception challenges, economic and financial sustainability concerns, and finally, operational challenges. Effective collaboration between airlines, travel agencies, and local governments is crucial for encouraging customer participation in regional connectivity schemes like UDAN. Enhancing customer awareness about the scheme and clearly communicating available options can make the scheme more accessible and appealing. Economic and financial sustainability is another critical issue, as the viability of airlines under UDAN depends on the availability of VGF. This creates uncertainty for travel agents, particularly regarding potential reductions or withdrawals of VGF. Lastly, operational challenges, particularly related to last-mile connectivity, remain a concern for many customers using UDAN flights. The challenges, ranked in order of priority, are summarised in Table 3.10.

Table 3. 10

Pairwise comparison of challenges for travel agent's category

Main Criteria	CR	Sub-criteria	Weights	Rank
Government and stakeholder support	0.073	Effectiveness of subsidies	0.21	3
		Role of cross-subsidisation	0.39	1
		Collaboration between airlines, travel agencies, and local governments	0.40	2
Customer awareness and perception challenge	0.027	Initial confusion about UDAN routes	0.23	3
		Perception of reliability and comfort	0.46	1
		Comparison with train services	0.31	2
Economic and financial sustainability	0.092	Balancing affordability and profitability	0.30	3
		Dependence on government subsidies	0.38	1
		Achieving economies of scale	0.31	2
Operational challenges	0.045	Availability of flights	0.19	3
		Inconvenient flight timings	0.26	2
		Connectivity issues (intermodal transport)	0.49	1
		Luggage restrictions	0.06	4

3.4.4.2 Government and stakeholder support

Cross-subsidisation under UDAN scheme makes regional air travel affordable by using metro route profits to subsidise less profitable regional routes. However, this creates challenges for travel agents, as price distortions (H. Wu et al., 2024) affect fare transparency. Agents face difficulties explaining pricing variations, leading to customer dissatisfaction. Fluctuating subsidies further complicate price forecasting and booking management. Effective collaboration between airlines, travel agencies, and local governments is crucial but hindered by inconsistent communication. This leads to misinformation about flight schedules, availability, and pricing. A lack of coordinated promotional efforts for regional routes hampers marketing opportunities, limiting the growth of these destinations. The adequacy and timeliness of subsidies are critical for maintaining affordable air travel. Insufficient or delayed subsidies increase airlines' operational costs, potentially raising prices for tier-1 city flights and reducing regional route appeal. Uncertainty around subsidy continuation disrupts travel agents' long-term sales strategies and affects revenue generation.

3.4.4.3 Customer awareness and perception challenges

Though more than 10 million passengers have utilised UDAN scheme (PTI, 2022), many passengers perceive regional UDAN flights as unreliable, often associating them with delays, cancellations, or limited-service frequency. This perception becomes particularly problematic when contrasted with the established airline routes serving metropolitan destinations. Additionally, smaller aircraft on UDAN routes are often seen as less comfortable, further discouraging travellers. In regions with strong train networks, air travel under UDAN must compete with the comfort, reliability, and affordability of trains. Convincing customers to prefer air travel under UDAN over trains remains challenging for travel agents and online providers due to trains' superior last-mile connectivity and cost-effectiveness. Regional airports' remote locations and additional airport processes further discourage passengers.

O'Connell and Williams (2006) highlighted the significant growth of domestic air travel in India, driven by a shift from buses and trains to air transport, though this growth was concentrated on metro routes where air travel's convenience was more apparent. Das et al. (2022) also noted that RCS connects cities with national educational institutions, but confusion regarding routes and airlines persists, especially in less urbanised areas, requiring extra effort from agents to educate customers.

3.4.4.4 Economic and financial sustainability

The financial sustainability of travel agents and online service providers is heavily influenced by airlines' dependence on government subsidies through the scheme. Though the scheme aims to make air travel affordable by offering VGF to airlines the stability of these subsidies is uncertain. A reduction or withdrawal of subsidies could lead airlines to increase ticket prices or cut flight frequencies, adversely affecting travel agents who rely on consistent and affordable flight options (Lee & Worthington, 2014; Mallikarjun, 2015). Achieving economies of scale poses a challenge due to lower passenger volumes on routes connecting remote regions, limiting cost reductions for airlines and bulk booking opportunities for travel agents. The International Air Transport Association (IATA) highlights the importance of economies of scale in reducing seat costs and shaping pricing strategies. Sindhwani et al. (2024) suggest that a hub network could mitigate operational risks and improve sustainability. Additionally, balancing affordability with subsidy dependency remains difficult, with reduced subsidies potentially straining airlines, affecting service quality, frequency, and customer satisfaction.

3.4.4.5 Operational challenges

Travel agents and online service providers under UDAN scheme encounter several operational challenges. Most stakeholders were concerned that a significant issue is connectivity, particularly with intermodal and last-mile transport. Passengers traveling to or from remote airports often face inadequate transportation links, which diminishes the appeal of regional air travel. Although the latest UDAN phase (5.2) aims to improve connectivity, inefficiencies in integrating transport modes such as buses and taxis continue to persist (Chaudhary, 2023; Gaurav, 2023). This complicates marketing efforts for travel agents, as poor access may deter customers. Inconvenient flight timings, as noted by DGCA, often misalign with passenger preferences, leading to lower occupancy rates and reduced attractiveness of UDAN flights. Additionally, AAI highlights that limited weekly flights on many routes restrict travel flexibility and challenge travel agents in offering viable packages, especially during peak seasons. Lastly, the use of smaller aircraft under the UDAN Scheme imposes stricter baggage policies, further deterring potential passengers.

3.4.4.6 Overall ranking of sub-challenges

From the perspective of travel agents and service providers (see Table 3.11), government support, passenger perception, and operational connectivity play a decisive role in the success of the UDAN scheme. Collaboration between airlines, travel agencies, and local governments (Rank 1) emerges as the most critical factor, emphasising the necessity of coordinated efforts to facilitate smooth operations and increase demand.

Table 3. 11

Comparison of local and overall weights for travel agent's sub-challenges

Sub-criteria	Local weight	Local rank	Overall weight	Overall rank
Collaboration between airlines, travel agencies, and local governments	0.358	2	0.142	1
Role of cross-subsidisation	0.358	1	0.141	2
Perception of reliability and comfort	0.249	1	0.114	3
Connectivity issues (Intermodal Transport)	0.176	1	0.087	4
Dependence on government subsidies	0.216	1	0.083	5
Comparison with train services	0.249	2	0.077	6
Effectiveness of subsidies	0.358	3	0.076	7
Achieving economies of scale	0.216	2	0.068	8
Balancing affordability and profitability	0.216	3	0.065	9
Initial confusion about UDAN routes	0.249	3	0.058	10
Inconvenient flight timings	0.176	2	0.046	11
Availability of flights	0.176	3	0.034	12
Luggage Restrictions	0.176	4	0.010	13

The role of cross-subsidisation (Rank 2) is equally vital, as financial redistribution mechanisms ensure the viability of routes and services, particularly in underserved regions. Passenger perception of reliability and comfort (Rank 3) further underscores the importance of maintaining a consistent and trustworthy travel experience to build demand and customer confidence. Operational efficiency and infrastructure are key concerns for travel service providers. Intermodal transport connectivity (Rank 4) is crucial, as seamless integration with other transport systems enhances accessibility and convenience for passengers. Additionally, dependence on government subsidies (Rank 5) reflects the reliance on financial assistance to maintain route viability. A comparative perception between air travel and train services (Rank 6) highlights a crucial challenge: air travel under UDAN must present clear advantages over rail networks to attract passengers. From a financial sustainability standpoint, effectiveness of subsidies (Rank 7) and achieving economies of scale (Rank 8) are essential to ensuring long-term viability. Balancing affordability and profitability (Rank 9) remains a concern, as ticket pricing needs to be competitive while ensuring financial sustainability for stakeholders. Passenger awareness and operational concerns also influence the performance of the UDAN scheme. Initial confusion about UDAN routes (Rank 10) suggests that better marketing and information dissemination are needed. Inconvenient flight timings (Rank 11) and availability of flights (Rank 12) reflect practical barriers that limit service utilisation. Lastly, luggage restrictions (Rank 13) are the least significant but still a relevant factor in customer satisfaction.

In summary, travel agents and service providers emphasise government collaboration, financial support mechanisms, passenger perception, and seamless connectivity as key determinants of success for the UDAN scheme. Addressing these factors through improved coordination, better marketing strategies, and enhanced intermodal transport integration will be crucial in sustaining the initiative's long-term impact.

3.4.5 Synthesis of common themes across stakeholders

While the previous sections present stakeholder perspectives separately to preserve the distinct insights of each group, Table 3.12 synthesizes these findings around shared themes. This demonstrates the points of agreement and divergence across stakeholders and provides integrated recommendations, as suggested by the examiner, without losing the clarity of the original stakeholder-specific analysis.

Table 3. 12

Cross-stakeholder thematic summary

Shared Theme	Airline Perspective	Airport Perspective	Regulator Perspective	Travel Agent Perspective	Integrated Recommendation
Infrastructure & Connectivity	Emphasised limited ground support and lack of intermodal integration	Focused on runway and terminal readiness; slow CAPEX execution	Highlighted delays in land acquisition and asset certification	Concerned with limited accessibility and poor route information	Establish a centralised infrastructure task force to coordinate project readiness, streamline land clearance, and ensure multimodal connectivity at smaller airports.
Financial Sustainability	Stressed dependence on VGF and low load factors	Cited poor revenue recovery and high operating costs	Identified absence of steady revenue sources in regional airports	Pointed out pricing irregularities due to subsidy fluctuations	Design a phased subsidy rationalisation plan with performance-linked disbursements and encourage joint public–private revenue generation models.
Stakeholder Coordination	Reported weak state–federal alignment on operational issues	Highlighted poor communication with airlines and regulators	Observed fragmented policy implementation	Noted inconsistent coordination with airlines and government	Implement a unified governance platform for information sharing among MoCA, AAI, carriers, and travel intermediaries to improve transparency and coordination.
Customer Awareness & Market Development	Targeted low demand on remote routes	Not a primary concern	Considered demand stimulation secondary to infrastructure	Highlighted low awareness and perceived unreliability of UDAN flights	Coordinate outreach to enhance UDAN's visibility and passenger confidence.

3.5 Policy implications and conclusion

Valuable insights from the data analysis and AHP-based prioritisation of challenges provide policymakers with critical pathways to enhance decision-making and strengthen India's regional connectivity framework.

3.5.1 Policy Implications for airlines based on data insights

From a policy perspective, the primary challenges faced by participating airlines under the UDAN scheme revolve around urban integration and accessibility, financial incentives and concessions, load factors and seat occupancy, the availability of suitable aircraft, and the readiness of the support system, such as ATC etc. Addressing the urban integration and accessibility challenge requires aligning airport development with broader regional transportation plans and ensuring seamless connectivity with urban and rural transport networks. Such integration will enhance passenger demand and reduce operational inefficiencies. Financial incentives and concessions must be streamlined and standardised to ensure timely and consistent support, particularly addressing the bureaucratic delays and discrepancies in VGF disbursements. Enhancing financial predictability would allow airlines to focus on optimising operations and improving service quality especially serving remote regions. This challenge highlights the importance of revenue diversification, as evidenced by findings from Germany and Austria, where passenger traffic from LCCs alone rarely sustains long-term growth and viability (see Červinka & Matušková, 2018).

Load factor and seat occupancy remain critical to the scheme's success, with policies needing to emphasise realistic fare caps that balance affordability with operational sustainability. Targeted strategies such as dynamic pricing models and effective marketing campaigns for regional routes could help airlines achieve better seat utilisation. Investment in suitable regional aircraft, such as the indigenously developed SARAS MKI & II[8], could significantly improve operational efficiency and cost management while supporting the “Make in India” initiative. The availability of localised MRO facilities is crucial for minimising aircraft downtime and reducing operating costs, but this domain in India remains in its early stages of development. Additionally, the readiness of the support system is vital for smooth operations. Enhanced ATC capabilities, exemplified by the Centralised Air Traffic Flow Management (C-ATFM) initiative by the AAI, have already demonstrated improvements in airspace utilisation and reductions in airborne delays and fuel consumption.

Future developments, such as the Indian Single Sky Harmonised (ISHAN) air traffic management system, promise to consolidate the country's four Flight Information Regions (FIRs) and centralise operations to improve safety, reduce costs, and enhance airspace management (Chopra, 2024). However, these advancements must be backed by detailed studies to assess their long-term implications. By prioritising these core challenges, policymakers can enable airlines to operate sustainably and support the broader objectives of the UDAN scheme. Future policies should integrate aviation growth with regional infrastructure development, taking cues from the success of high-speed rail and airport integration in Western economies and Japan (Albalate et al., 2015; Giri, 2018). Additionally, given the limitations of initiatives like Pawan Hans due to small seating capacities (MoCA, 2020), it is evident that policy-driven investment in regional aviation infrastructure is crucial. Strengthening support systems and aligning market demand with the readiness of infrastructure and operations will be key to ensuring the long-term success and sustainability of the UDAN scheme.

[8] NAL Saras is an Indian multi-purpose civilian aircraft in the light transport aircraft category, designed by the National Aerospace Laboratories, (NAL).

3.5.2 Policy directions for enhancing regional airport viability

To ensure the long-term success of the scheme, policy measures must directly target the critical challenges faced by participating airports. Addressing inadequate infrastructure and connectivity should be a top priority, with strategic investments to upgrade facilities, including parking bays, passenger terminals, and night landing capabilities, ensuring airports can meet operational demands. Policies must also focus on financial sustainability by incentivising innovative revenue models that reduce reliance on aeronautical charges. Airports should be encouraged to develop ancillary revenue streams (Avram, 2017; Shaw et al., 2021), such as retail spaces, cargo services, and property leasing, to offset the lack of income from RCS flights. Improving urban integration and accessibility through multimodal transport systems, such as seamless road, rail, and air connections, can enhance the attractiveness of regional air travel and boost passenger volumes.

Furthermore, policymakers must streamline bureaucratic processes, delineate responsibilities clearly between central and state authorities, and implement a more efficient regulatory framework to reduce delays and operational inefficiencies. Public-private partnerships should be actively promoted to facilitate infrastructure development and ensure efficient airport management. These measures, combined with targeted financial support mechanisms, can enhance the sustainability and operational efficiency of RCS airports, enabling them to fulfil the scheme's broader goals of regional connectivity and economic development (Iyer & Thomas, 2020; PwC, 2022).

Privatisation offers a promising pathway for improving the financial and operational efficiency of regional airports under the UDAN scheme. While success stories like Cochin International Airport Limited (CIAL) and the greenfield airports in Bangalore and Hyderabad have largely emerged from Tier 1 cities, they highlight the potential benefits of private sector involvement in airport management. These initiatives have demonstrated enhanced infrastructure development, streamlined operations, and significant aviation growth (Ohri, 2012). Policymakers should explore similar models for regional airports, ensuring that privatisation strategies are tailored to the unique challenges and opportunities of Tier 2 and Tier 3 airports. With careful evaluation of contextual factors and robust regulatory frameworks, privatisation can drive sustainable growth and improve regional connectivity.

3.5.3 Regulatory policy implications for strengthening UDAN

The policy implications for the UDAN scheme, from the perspective of the DGCA, revolve around addressing the core challenges of asset readiness, revenue generation, and the underdeveloped ecosystem for smaller airlines. To mitigate these issues, the DGCA must prioritise accelerating the development of critical infrastructure at regional airports, ensuring timely asset readiness and overcoming land acquisition delays. Furthermore, the regulator should facilitate the creation of a supportive financial and operational environment for small airlines, addressing their access to affordable financing, skilled labour, and maintenance facilities. This can be achieved through targeted policy adjustments, such as subsidies and financial incentives for airlines participating in the scheme. Additionally, fostering partnerships between stakeholders and promoting flexibility in regulatory frameworks will help build a more robust and sustainable ecosystem, capable of supporting the long-term goals of regional connectivity. To achieve the long-term goals of enhancing connectivity and economic growth, the DGCA must focus on these critical areas, fostering a more resilient and self-sustaining regional aviation ecosystem. This includes preventing unsustainable pricing and ensuring fair competition. Additionally, the DGCA should establish clear, consistent, and predictable regulatory frameworks to facilitate regional connectivity, streamline approval processes, and collaborate with stakeholders for effective long-term planning.

3.5.4 Policy implications for travel agents in regional connectivity

For travel agents, the UDAN scheme presents significant policy challenges that require targeted interventions to enhance its effectiveness and sustainability. The cross-subsidisation mechanism, while critical to maintaining affordability, creates unintended complexities such as fare distortions and unpredictable pricing structures that strain the operational capacity of travel agents (Fageda et al., 2018; Iyer & Thomas, 2020). To address this, policymakers must establish a more transparent and predictable pricing framework, ensuring that cross-subsidisation does not impede the ability of agents to provide clear and competitive pricing to customers. Additionally, the timely and consistent distribution of government subsidies is essential to minimise disruptions in regional flight operations, as inconsistent funding directly impacts the ability of travel agents to market and sell these routes effectively. Enhancing coordination between airlines, government bodies, and travel agents is crucial to aligning promotional strategies and communicating subsidy-related benefits more clearly to the end consumer.

Another critical policy implication lies in addressing the perception of regional UDAN flights as unreliable and uncomfortable compared to alternative transport modes such as trains, which often offer better last-mile connectivity. To overcome this, government policies must prioritise investments in improving the operational reliability of regional airlines and the quality of passenger experience, including ensuring convenient intermodal transport options to enhance accessibility. An implementation suggestion is to adopt policies encouraging the use of carry-on luggage as evidenced by Eisenhut et al. (2021), particularly with smaller aircraft, as this practice has been shown to significantly reduce turnaround times and improve operational efficiency.

Furthermore, given the scheme's dependence on government subsidies, which undermines its economic sustainability, a gradual shift toward incentivising private sector investment and fostering self-sustaining business models could reduce over-reliance on public funds. Travel agents play a pivotal role in bridging the gap between customers and regional aviation services, but their effectiveness depends heavily on policies that address structural challenges such as limited connectivity, suboptimal flight schedules, and the lack of intermodal transport infrastructure. Policymakers must take a proactive approach in addressing these interconnected issues, recognising that travel agents are essential stakeholders in the successful implementation and continuation of the regional connectivity.

3.5 Conclusion

In conclusion, the UDAN scheme is a significant initiative for enhancing India's regional air connectivity, but its long-term success hinges on addressing critical infrastructure and financial challenges. Policymakers must prioritise improvements in regional airport infrastructure, intermodal connectivity, and the alignment of airport development with broader transportation strategies. Key steps include streamlining coordination between aviation and other transport sectors, standardising financial incentives, and alleviating regulatory burdens. Further, encouraging investment in Indian regional airports, optimising fare structures, and promoting ancillary revenue streams are vital for stabilising financial performance and ensuring long-term viability.

While this research utilised the AHP to systematically analyse stakeholder perspectives, the method's reliance on subjective judgments underscores potential biases in ranking challenges, particularly given the small and diverse sample size. Additionally, the complexity of conducting pairwise comparisons for multi-faceted schemes like UDAN may have limited the scope of this research in fully addressing the interdependencies between challenges. A comprehensive approach that integrates these elements can effectively bridge the gap between UDAN's connectivity aspirations and operational realities. Learning from successful models in emerging economies, such as high-speed rail integration and effective last-mile connectivity, can help create a resilient, India-specific regional aviation model. Looking ahead, future research should evaluate the efficacy of emerging UDAN initiatives, such as water aerodromes and helicopter services, which were beyond the scope of this research. There is also significant potential in examining the endogeneity of travel times, particularly how travellers' choices affect traffic congestion within transportation networks. Another promising avenue for exploration is the Krishi UDAN initiative, specifically focusing on its role in transporting perishable agricultural products, which this study did not address. Further investigation into these areas, alongside the socio-economic impacts of UDAN across Indian regions, could provide deeper insights into optimising the scheme's contributions to economic growth and connectivity objectives.

General Discussion

Linking back to the research objectives

This thesis addressed three interlinked research objectives aimed at understanding the financial performance, infrastructural resilience, and policy implementation challenges within India’s aviation sector—particularly in the wake of the COVID-19 pandemic. The first study examined the financial determinants of Indian airlines, revealing that higher expenditure on staffing, fleet operations, and strategic participation in regional schemes and alliances—especially under private ownership—was associated with stronger performance, despite structural inefficiencies. The second study assessed the resilience of India’s ten busiest airports using BVAR and OLOGIT models, highlighting disparities in post-pandemic recovery and the critical role of infrastructure in supporting operational continuity. The final study employed a stakeholder-based qualitative approach to investigate the challenges of India’s UDAN regional connectivity scheme, uncovering misalignments between policy design and local execution, and emphasising the need for better stakeholder coordination and infrastructure alignment at the regional level. Collectively, these studies confirm that India’s aviation landscape cannot be understood through isolated perspectives; rather, its financial health, infrastructural capacity, and policy frameworks are deeply interconnected. A coherent recovery and long-term growth trajectory will depend on integrated strategies that address these dimensions in tandem, especially as India aspires to emerge as a global aviation hub.

Policy Implications

A number of practical recommendations emerge from this research, particularly in the aftermath of COVID-19. These implications are not isolated to a single study, but cut across the financial, operational, and policy domains of aviation. Table 4.1 summarises six key policy suggestions drawn from the empirical evidence presented.

Table 4. 1

Key policy insights and implications

Chapter	Policy implications
Chapter 1	Align airline expenditure with data-driven planning to improve financial sustainability.
	Reform UDAN support mechanisms to improve financial viability for regional carriers.
Chapter 2	Prioritise infrastructure upgrades at Tier 2/3 airports to build resilience and support RCS schemes.
	Integrate resilience planning into national airport management using predictive models.
Chapter 3	Strengthen multi-modal infrastructure and introduce performance-linked UDAN subsidies
	Implement performance-linked funding for UDAN routes to improve accountability.
	Foster private sector participation and financial innovation in regional aviation.

Among the policy insights and implications presented in this thesis, the following three key recommendations are particularly noteworthy and will be discussed in detail. These were selected based on their recurring emphasis across the three studies and their potential to offer meaningful guidance to aviation stakeholders, including policymakers, regulators, and industry partners.

Align airline expenditure with data-driven planning to improve financial sustainability

The findings presented in Chapter 1 highlight the critical need for airlines to adopt data-driven expenditure strategies to strengthen their financial sustainability. By utilising advanced forecasting and analytics tools, airlines can more accurately align operational costs with revenue projections, thereby reducing inefficiencies and improving budget management. This approach is especially vital in the highly competitive and dynamic Indian aviation market, where fluctuating demand and external shocks can significantly impact profitability. Moreover, the growing integration of RCS routes has shown a positive impact on airline revenues, particularly in underserved regions. Therefore, incorporating data-driven planning into expenditure decisions not only enhances financial discipline but also enables airlines to better anticipate market trends and optimise resource allocation—ultimately contributing to more resilient and financially stable operations.

Prioritise infrastructure upgrades at Tier 2/3 airports to build resilience and support regional connectivity scheme

Chapter 2 underscores the importance of targeted infrastructure investments at Tier 2 and Tier 3 airports to improve their operational resilience and support the broader goals of RCS. Enhancing facilities and upgrading airport infrastructure in these underserved regions not only addresses capacity constraints but also strengthens the overall air transport network by ensuring reliable service delivery. These improvements are fundamental for sustaining the viability of RCS routes and promoting balanced regional development. By focusing on the resilience of smaller airports, stakeholders can mitigate service disruptions and foster more inclusive connectivity that benefits local economies and communities.

Strengthen multi-modal infrastructure and introduce performance-linked UDAN subsidies

Chapter 3 emphasises the need to integrate infrastructure upgrades that facilitate multi-modal transport connections, as these improvements enhance passenger convenience and accessibility, extending the benefits of regional air connectivity beyond the airport itself. Furthermore, the chapter highlights the necessity of reforming the UDAN subsidy framework to incorporate greater accountability through measurable performance indicators. By linking subsidies to specific outcomes, this performance-based model not only incentivises efficient resource use and improved service quality but also ensures that financial support drives tangible improvements. When coupled with infrastructure integration, such a subsidy approach supports long-term sustainability and fosters seamless regional mobility.

Conclusion

Summary

This PhD thesis offers a comprehensive examination of the Indian aviation industry's growth, operational challenges, and resilience, focusing on developments spanning the pre- and post-COVID-19 periods. Through three interrelated studies, the thesis provides empirical insights and strategic recommendations that are relevant for policymakers, aviation stakeholders, and researchers navigating a rapidly evolving sector.

Chapter 1 investigated the development of Indian airlines, in which Study One focused on the determinants of Indian airline revenues. Using panel data from 2007 to 2022 and addressing endogeneity through IV regression and GMM techniques, an aspect often overlooked in earlier studies, it finds that unit expenditure, passenger volume, staff strength, alliance membership, and participation in the UDAN scheme all positively influence revenue. These findings highlight how Indian airlines—whether state-owned or private—must carefully manage operational costs while enhancing factors that drive market growth and retention, particularly in terms of passenger number, in order to remain financially viable in a volatile environment shaped by regulatory shifts, fluctuating input costs, and market competition. Importantly, it also revealed the positive influence of the UDAN scheme on the Indian airline sector, indicating its critical role in supporting regional connectivity and contributing to broader national aviation objectives. The analysis further revealed how ownership structures, business models, and strategic alliances shaped financial outcomes, affirming the importance of sustained investment and operational efficiency in fostering long-term airline growth.

Building on these insights, Chapter 2 assessed the development of Indian airports that provide basic infrastructure for the airlines' market growth. Particularly, Study Two evaluated how India's ten busiest airports recovered from the COVID-19 pandemic in terms of passenger and cargo traffic. In this Study, an empirical model utilising Bayesian forecasting was used to compare the actual and predicted performance of the airports, both for passengers and cargo, enabling the classification of airports as outperformers, forecast achievers, or underperformers. Further analysis using OLOGIT regression reveals that infrastructure factors such as runway capacity, cargo terminals, and metro access significantly correlate with post-pandemic recovery, underscoring the critical role of infrastructure preparedness and adaptability in aviation planning. The study evaluated how airports recovered in terms of passenger and cargo operations. The results showed that while airports with robust infrastructure rebounded more effectively, even the largest hubs experienced significant setbacks during the pandemic. These findings underscore the urgent need to modernise infrastructure, strengthen cargo operations, and adopt adaptive resilience strategies aligned with global standards—especially as India's domestic aviation sector continues to grow and regional schemes like UDAN expand connectivity.

Chapter 3 examined another aspect of the Indian aviation sector, the regional connectivity. As pointed out in Chapter 1, the UDAN scheme plays an important role in the development of Indian airlines. Meanwhile, it also provides incentive for Indian airports to invest and improve their infrastructure, which has been highlighted as an important factor for airport development by Chapter 2. In this sense, Study Three examined the implementation and sustainability of the UDAN scheme from the perspectives of the four key stakeholders, including airlines, airports, regulators, and travel agents. Using the AHP to analyse the responses of those stakeholders regarding the challenges of UDAN, the study identifies infrastructure bottlenecks, financial viability concerns, and regulatory uncertainty as the most pressing issues, reflecting the complex interplay of policy design and operational realities in expanding regional air connectivity. This qualitative inquiry identified persistent challenges such as infrastructure limitations, bureaucratic delays, inadequate state support, and poor inter-stakeholder coordination. Such findings, therefore, emphasised the necessity for improved collaboration, policy coherence, and targeted interventions to ensure the scheme's long-term viability and its alignment with India's broader aviation ambitions.

Together, these three studies offer a comprehensive and nuanced understanding of Indian aviation, shedding light on the financial, policy, and operational dynamics shaping Indian aviation today. They provide a timely contribution as India positions itself to expand its aviation footprint, driven by a growing domestic market, a rising number of passengers, and a surge in aircraft orders from major manufacturers. The thesis supports evidence-based policymaking and lays the groundwork for sustainable growth, emphasising the importance of strategic investments, multi-stakeholder collaboration, and adaptive resilience planning. By advocating for data-driven policymaking, integrated infrastructure strategies, and inclusive governance, this research contributes meaningfully to the discourse on aviation development—not only for India but for other emerging markets grappling with similar challenges and aspirations.

Limitations

While this thesis makes significant contributions to the understanding of the Indian aviation industry, several limitations should be acknowledged. In Chapter 1, the analysis was constrained by the availability and granularity of financial and operational data, particularly during the pandemic years. This limitation may have restricted the depth and robustness of certain findings related to airline revenue dynamics. Methodologically, the use of an advanced forecasting technique, BVAR in Chapter 2 introduced an innovative approach to forecasting; however, this method is also subject to limitations related to model assumptions, parameter sensitivity, and data quality. In Chapter 3, although efforts were made to capture a diverse range of stakeholder perspectives, the reliance on interviews and surveys from a limited pool of participants meant that views from smaller or less-represented regions and operators may not have been fully reflected. Moreover, all three studies are based on data available up to 2024. Given the rapidly evolving nature of the aviation sector, marked by technological advances, policy shifts, and market fluctuations, some conclusions drawn in this thesis may be subject to change as new developments unfold. Finally, while the findings offer valuable insights within the Indian context, they should be applied cautiously to other countries or regions, where industry structures and regulatory environments may differ significantly.

Future Research

Building upon the findings and limitations of this thesis, several avenues for future research are recommended. Extending the temporal scope of analysis would allow for a more comprehensive assessment of the long-term effects of policy reforms and post-pandemic recovery strategies. Future studies could also benefit from comparative analyses involving other emerging aviation markets to identify best practices and contextually adaptable strategies, particularly in regional connectivity and resilience planning. Incorporating the perspectives of additional stakeholders including passengers, airline employees, and smaller regional operators would provide a more holistic view of operational realities and customer service challenges in the aviation ecosystem. There is also a growing need to examine the environmental implications of aviation expansion in India, particularly in terms of carbon emissions, sustainability practices, and the adoption of green technologies. Furthermore, future research could explore the transformative role of digitalisation, artificial intelligence, and automation in enhancing operational efficiency, crisis response, and system resilience. Finally, rigorous policy impact evaluations and the development of dynamic, context-specific resilience frameworks tailored to the Indian aviation environment remain essential for supporting strategic planning and long-term industry sustainability.

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Appendices

Appendix A – Online interview questions

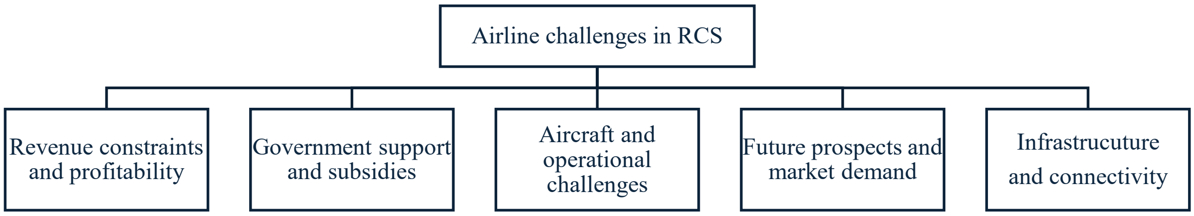
The appendices include supporting documents and resources used throughout the research process. Specifically, all stakeholders were provided with a two-part questionnaire. Section A captured demographic information, while Section B and C contained stakeholder-specific questions tailored to each group—airlines, airports, regulators, and travel agents. These instruments supported the qualitative and quantitative analysis presented in the thesis. The bipolar surveys were administered via the Qualtrics online survey platform (www.qualtrics.com), ensuring secure and structured data collection across all stakeholder groups.

Set A – Online questions for airline stakeholders

Section A: Demographic information

What is your gender?				
o Male	o Female	o Prefer not to say		
Please select your age range:				
o 18–25	o 26-35	o 36- 45	o 46 or above	
How long have you been working for the airlines?				
o Less than 3 years	o 3–5 years	o 5–7 years	o more than 7 years	
Which airline do you represent?				
o Air India	o SpiceJet	o IndiGo	o Alliance Air	o Other
What is your current designation in the airline?				

Section B: Online questionnaire for participating airlines



Prioritising the challenges of participating airlines under the UDAN scheme

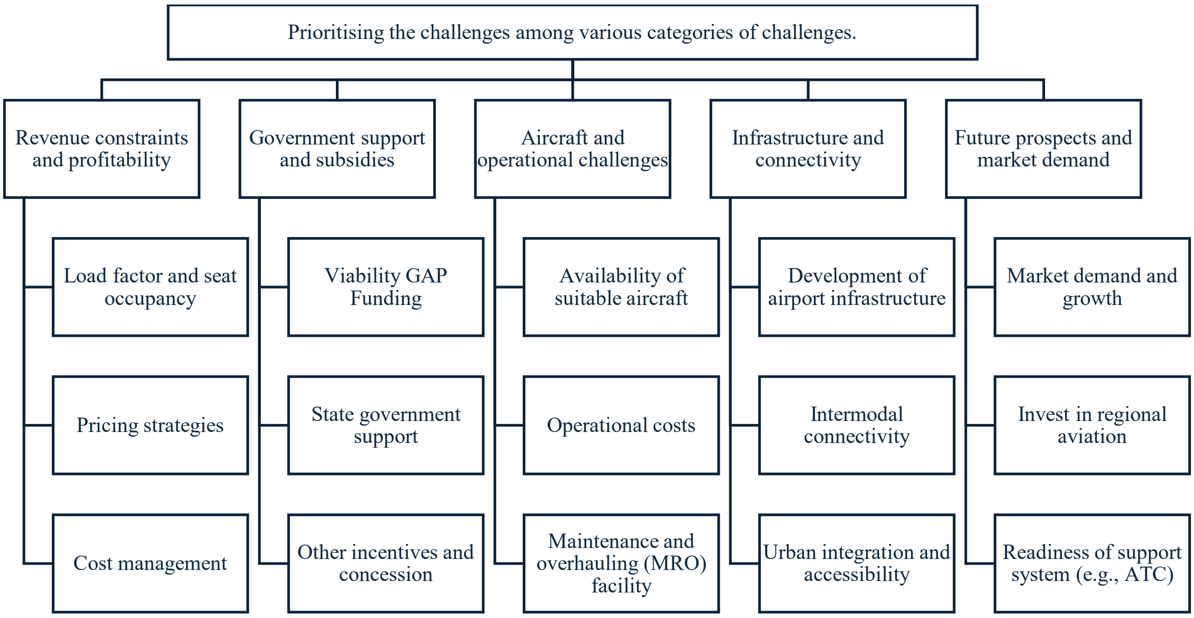
Challenges category	**Indicators**	**Definition**
Participating airlines challenges	*Revenue constrains and profitability*	The challenges airlines face in maintaining profitability under the UDAN scheme
	Government support and subsidies	Government support provided to airlines in various forms
	Aircraft operational challenges	Operational difficulty encountered by airlines
	Infrastructure and connectivity	Readiness of participating airports for connectivity.
	Future prospects	The upcoming challenges the airline might face such as travel demand and fuel prices

Q1. Which of the following indicators is ***relatively more important*** when ***considering the challenges*** for airlines participating in UDAN scheme? (please √ to indicate your answer**)**

Indicator A	**Extremely Agree**		**Very strongly Agree**		**Strongly Agree**		**Slightly Agree**		**Equal**	**Slightly Agree**		**Strongly Agree**		**Very strongly Agree**		**Extremely Agree**		**Indicator B**
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Revenue Constrains and profitability																		Government Support and subsidies
																		Aircraft and operational challenges
																		Infrastructure and connectivity
																		Future prospects and market demand
Government Support and Subsidies																		Aircraft and operational challenges
																		Infrastructure and connectivity
																		Future prospects and market demand

Aircraft and Operational Challenges																		Infrastructure and connectivity
																		Future prospects and market demand
Infrastructure and Connectivity																		Future prospects and market demand

Section C: Prioritising the challenges within different categories



Challenges category	Indicators	Definition
Revenue constraints and profitability	*Load factor and seat occupancy*	Improving aircraft utilisation and seat occupancy
	Pricing strategies	Ticket prices are capped in RCS routes
	Cost management	Higher operational cost in RCS routes
Government support and subsidies	*Viability Gap Funding*	Sufficiency of VGF for the airline
	State government support	Support from state government for facilitating UDAN scheme for the airline
	Financial incentives and concession	Financial incentives and other forms of support
Aircraft and operational challenges	*Availability of suitable aircraft*	Availability of suitable aircraft for RCS routes
	Operational cost in airlines	Higher day-to-day expenditure of airlines services in RCS routes

	Maintenance and overhauling facility	Challenges in the availability and affordability of MRO Facilities
Infrastructure connectivity	*Development of airport Infrastructure*	Inadequacy of airport infrastructure
	Intermodal connectivity	Lack of seamless connections and integration between different modes of transportation
	Urban integration	Access to urban amnesties and services, transportation etc.
Future prospects and market demand	*Market demand and growth*	Challenges affecting the potential growth of the RCS
	Investing in regional aviation	Airlines evaluating the potential for future investment in regional aviation
	Readiness of support system	Challenges in aviation infrastructure readiness for expanding RCS

Q2. Which of the following ***revenue constraint challenges*** is *relatively more important* for airlines participating in the UDAN scheme? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Load factor and seat occupancy																		Pricing strategies
																		Cost management
Pricing strategies																		Cost management

Q3. Which of the following ***support systems*** is ***relatively more important*** when considering the challenges for airlines in the UDAN scheme? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Viability GAP Funding																		State government support
																		Other incentives and concession
State government support																		Other incentives and concession

Q4. Which of the ***aircraft and operational challenges*** is ***relatively more important*** when considering the challenges for airlines in the UDAN scheme? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Availability of suitable aircraft																		Operational costs
																		Maintenance and overhauling (MRO) facility
Operational costs																		Maintenance and overhauling (MRO) facility

Q5. Which of the ***Infrastructure and connectivity challenges*** is ***relatively more important*** when considering the challenges for airlines in the UDAN scheme? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Development of airport infrastructure																		Intermodal connectivity
																		Urban integration and accessibility
Intermodal connectivity																		Urban integration and accessibility

Q6. When considering the ***future prospects and market demand***, which of the following is ***relatively more important*** to consider when operating in regional markets for airlines? (please √ to indicate your answer)

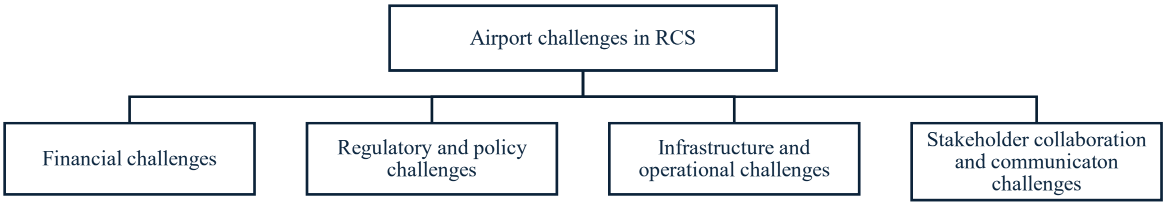
Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Market demand and growth																		Invest in regional aviation
																		Readiness of support system (e.g., ATC)
Invest in regional aviation																		Readiness of support system (e.g., ATC)

Set B – Online questions for airport stakeholders

Section A: Demographic information of airport staff

What is your gender?			
o Male	o Female	o Prefer not to say	
Please select your age range:			
o 18–25	o 26-35	o 36- 45	o 46 or above
Are you an airport employee?			
o Yes	o No	o I work for another organisation, but associated with airports	
How long have you been working for the organisation?			
o Less than 3 years	o 3–5 years	o 5–7 years	o more than 7 years
What is your current designation in the airport?			

Section B: Online questionnaire for participating airports:



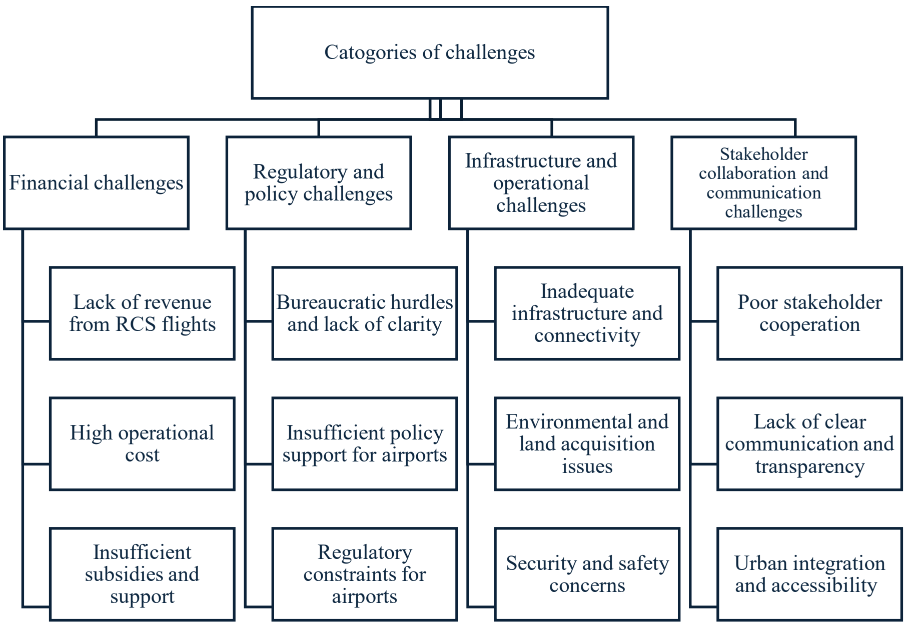
Prioritising the challenges of participating airlines under UDAN scheme.

Challenges category	**Indicators**	**Definition**
Participating airport challenges	*Financial challenges*	Airports face challenges in maintaining profitability under the UDAN scheme
	Regulatory challenges	Difficulty in evaluating the effectiveness of regulations and policies from various government and regulatory bodies
	Infrastructure and operational challenges	Challenges in assessing the adequacy and functionality of airport infrastructure
	Stakeholder collaboration and communication challenges	Ensuring effective stakeholder collaboration for successful airport participation remains a challenge

Q1. Which of the following indicators is relatively more important while considering the challenges for airports participating in the UDAN scheme?

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Financial challenges																		Regulatory and policy challenges
																		Infrastructure and operational challenges
																		Stakeholder collaboration and communication challenges
Regulatory and policy challenges																		Infrastructure and operational challenges
																		Stakeholder collaboration and communication challenges
Infrastructure and operational challenges																		Stakeholder collaboration and communication challenges

Section C: Prioritising the challenges within different categories



Challenges category	Indicators	Definition
Financial challenges	*Lack of revenue from RCS flights*	Minimal revenue due to government promotion of the UDAN scheme
	High operational costs	Elevated airport operating expenses under the UDAN scheme
	Insufficient subsidies and support	Government subsidies are insufficient
Regulatory and policy challenges	*Bureaucratic hurdles and lack of clarity*	Time-consuming bureaucratic processes and unclear division of responsibilities between state and central government
	Insufficient policy support for airports	Unclear and inadequate policies for airport support
	Regulatory constraints for airports	Regulatory hurdles impacting smooth airport operations
Infrastructure and operational challenges	*Inadequate Infrastructure and connectivity*	Insufficient infrastructure to support operations
	Environmental and land acquisition issue	Challenges with land acquisition and environmental compliance
	Security and safety concerns	Safety and security issues due to inadequate infrastructure
Stakeholder collaboration and communication challenges	*Poor stakeholder cooperation*	Lack of effective communication between stakeholders, leading to inefficiency in the UDAN scheme.
	Lack of clear communication and transparency	Misunderstandings causing planning inefficiencies
	Urban integration and accessibility	Inadequate transportation from airports to cities, lack of intermodal last-mile connectivity

Q2. Which of the following ***financial challenges*** is ***relatively more*** important for airports participating in the UDAN scheme? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Lack of revenue from RCS flights																		High operational cost
																		Insufficient subsidies and support
High operational cost																		Insufficient subsidies and support

Q3. Which of the following ***regulatory and financial challenges*** is ***more significant*** for airports participating in the UDAN scheme? (Please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Bureaucratic hurdles and unclear responsibilities (policy not being clear for a certain period)																		Insufficient policy support for airports
																		Regulatory constraints affecting operations
Insufficient policy support for airports																		Regulatory constraints affecting operations

Q4. Which of the following ***infrastructure and operational challenges*** is ***relatively more significant*** for airports participating in the UDAN scheme? (Please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Inadequate infrastructure and connectivity																		Environmental and land acquisition issues
																		Security and safety concerns
Environmental and land acquisition issues																		Security and safety concerns

Q5. Which of the following ***stakeholder collaboration and communication challenges*** is ***relatively more significant*** for airports participating in the UDAN scheme? (Please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Poor stakeholder cooperation																		Lack of clear communication and transparency
																		Urban integration and accessibility (last mile connectivity etc.)

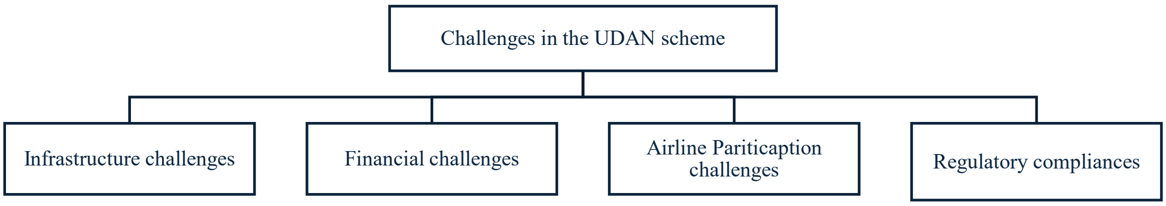
Lack of clear communication and transparency																		Urban integration and accessibility (last mile connectivity etc.)

Set C – Online questions for regulators

Section A: Demographic information of regulators

What is your gender?				
o Male	o Female	o Prefer not to say		
Please select your age range:				
o 18–25	o 26-35	o 36- 45	o 46 or above	
Which organisation do you work for?				
o MoCA	o DGCA	o AAI	o ADA	o Others
How long have you been working for the organisation?				
o Less than 3 years	o 3–5 years	o 5–7 years	o more than 7 years	
What is your current designation in the organisation?				

Section B: Online questionnaire for aviation regulators:



Prioritising the challenges of aviation regulators under the UDAN scheme

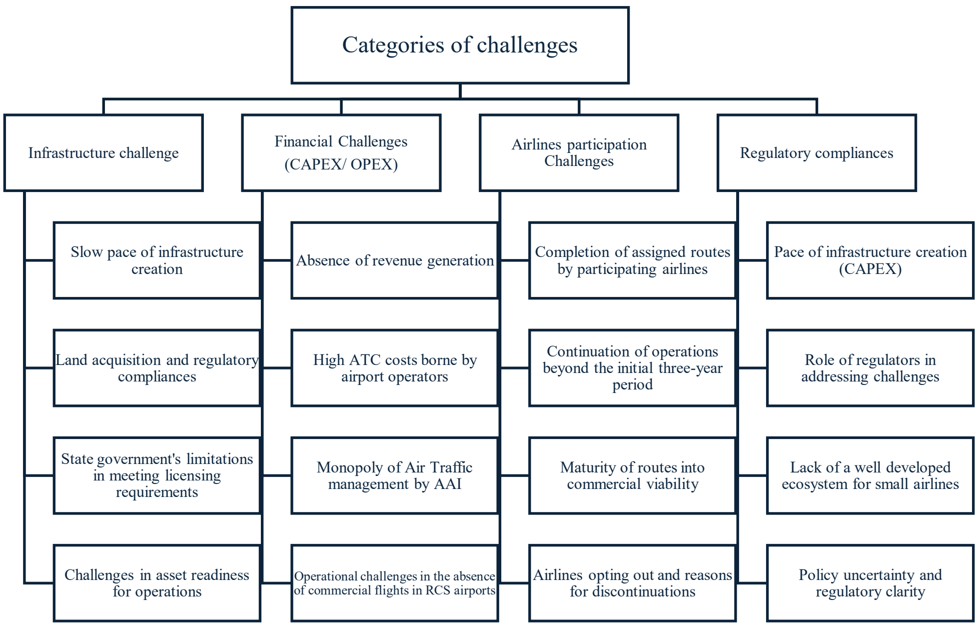
Challenges category	Indicators	Definition
Challenges in UDAN scheme (Regulators perspective)	*Infrastructure challenges*	Infrastructure challenges faced by airlines and airports in the successful implementation of UDAN scheme
	Financial challenges	Financial challenges faced by airport operators (e.g., CAPEX/ OPEX)

	Airline participation challenges	Challenges encountered by airlines in the scheme
	Regulatory challenges	The challenges faced by regulators in successfully implementing the scheme

Q1. Which of the following ***challenges*** is ***relatively more important*** when considering the challenges from the regulator's perspective in participating in the UDAN scheme and continuing its implementation?

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Infrastructure challenges																		financial challenges
																		Airline participation challenges
																		Regulatory compliances
Financial challenges																		Airlines participation challenges
																		Regulatory challenges
Airlines participation challenges																		Regulatory challenges

Section C: Prioritising the challenges within different categories



Challenges category	Indicators	Definition
Infrastructure challenges	*Slow-paced Infrastructure creation*	Slow pace of infrastructure development hindering UDAN progress
	Land acquisition and regulatory compliance	Challenges in land acquisition and meeting regulatory requirements for airport development
	State government's limitation in regulatory compliance	Constraints faced by state governments in meeting regulatory standards
	Challenges in asset readiness for operations	Delays and issues impacting asset readiness and operational timelines
Financial challenges	*Absence of revenue generation*	Airlines receive financial assistance while airports struggle to generate revenue from RCS flights
	High ATC costs borne by airport operators	Airports bear significant costs for air traffic control related to RCS flights
	Monopoly of air traffic management	AAI's monopoly on air traffic management impacts airport operations
	Operational challenges without commercial flights	Financial viability of RCS airports relies heavily on non-RCS flights
Airline participation challenges	*Competition on Assigned Routes*	Increased competition among airlines on RCS routes, leading to reduced revenue
	Continuation of operations beyond initial three-year period	Evaluating whether airlines continue or discontinue participation after the initial three-year period
	Maturity of routes into commercial viability	Assessing if routes become mature enough for airlines to operate without VGF
	Airlines opting out and reasons for discontinuation	Increasing number of airlines discontinuing participation due to various challenges
Regulatory compliance	*Pace of infrastructure creation (CAPEX/ OPEX)*	Insufficient infrastructure development for the RCS scheme hampers its implementation
	Role of regulators in addressing challenges	Regulations inadequately address the practical challenges of the scheme

	Lack of a well-developed ecosystem for small airlines	The ecosystem for smaller airlines under RCS faces operational hurdles
	Policy uncertainty and regulatory clarity	Ambiguity in policies by regulatory bodies which affects the execution of the UDAN scheme.

Q2. Which ***infrastructure challenge*** is ***relatively more significant*** for regulators participating in the UDAN scheme, particularly in facilitating its implementation? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Slow pace Infrastructure creation																		Land acquisition and regulatory compliances
																		State government's limitations in meeting licensing requirements
																		Challenges in asset readiness for operations
Land acquisition and regulatory compliances																		State government's limitations in meeting licensing requirements
																		Challenges in asset readiness for operations
State government's limitations in meeting licensing requirements																		Challenges in asset readiness for operations

Q3. Which of the following ***financial challenges*** is ***more significant*** for airports participating in the UDAN scheme? (Please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale

Absence of revenue generation																		High ATC costs borne by airport operators
																		Monopoly of Air Traffic management by AAI
																		Operational challenges in the absence of commercial flights in RCS airports
High ATC costs borne by airport operators																		Monopoly of Air Traffic management by AAI
																		Operational challenges in the absence of commercial flights in RCS airports
Monopoly of Air Traffic management by AAI																		Operational challenges in the absence of commercial flights in RCS airports

Q4. Which of the following ***challenges related to airline participation*** is ***relatively more significant*** for airlines participating in the UDAN scheme? (Please √ to indicate your answer)

Indicator A	Extremely		Very strongly		Strongly		Slightly		Equal	Slightly		Strongly		Very strongly		Extremely		Indicator B
	agree		agree		agree		agree			agree		agree		agree		agree		
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Competition of assigned routes by participating airlines																		Continuation of operations beyond the initial three-year period
																		Maturity of routes into commercial viability
																		Airlines opting out and reasons for discontinuations
Continuation of operations beyond the initial three-year period																		Maturity of routes into commercial viability
																		Instances of airlines opting out and reasons for discontinuations
Maturity of routes into commercial viability																		Instances of airlines opting out and reasons for discontinuations

Q5. Which of the following ***regulatory compliance challenge*** is ***relatively more significant*** for airports participating in the UDAN scheme? (Please √ to indicate your answer)

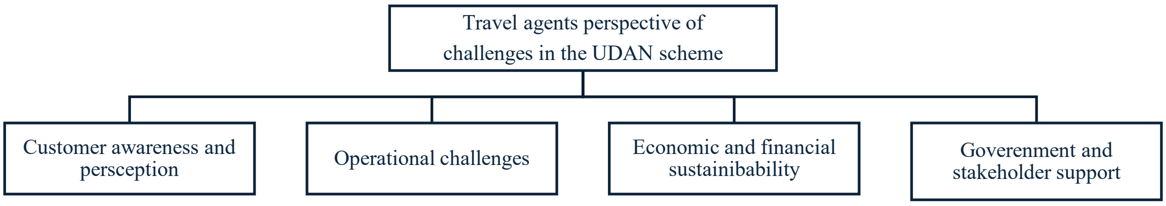
Indicator A	Extremely		Very strongly		Strongly		Slightly		Equal	Slightly		Strongly		Very strongly		Extremely		Indicator B
	agree		agree		agree		agree			agree		agree		agree		agree		
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Pace of infrastructure creation (CAPEX)																		Role of regulators in addressing challenges
																		Lack of a well developed ecosystem for small airlines
																		Policy uncertainty and regulatory clarity
Role of regulators in addressing challenges																		Lack of a well-developed ecosystem for small airlines
																		Policy uncertainty and regulatory clarity
Lack of a well developed ecosystem for small airlines																		Policy uncertainty and regulatory clarity

Set D – Online questions for travel agencies

Section A: Demographic information of travel agents

What is your gender?				
o Male	o Female	o Prefer not to say		
Please select your age range:				
o 18–25	o 26-35	o 36- 45	o 46 or above	
How long have you been working for the organisation?				
o Less than 3 years	o 3–5 years	o 5–7 years	o more than 7 years	
Which travel agency are you employed by				

Section B: Online questionnaire for Travel agents:



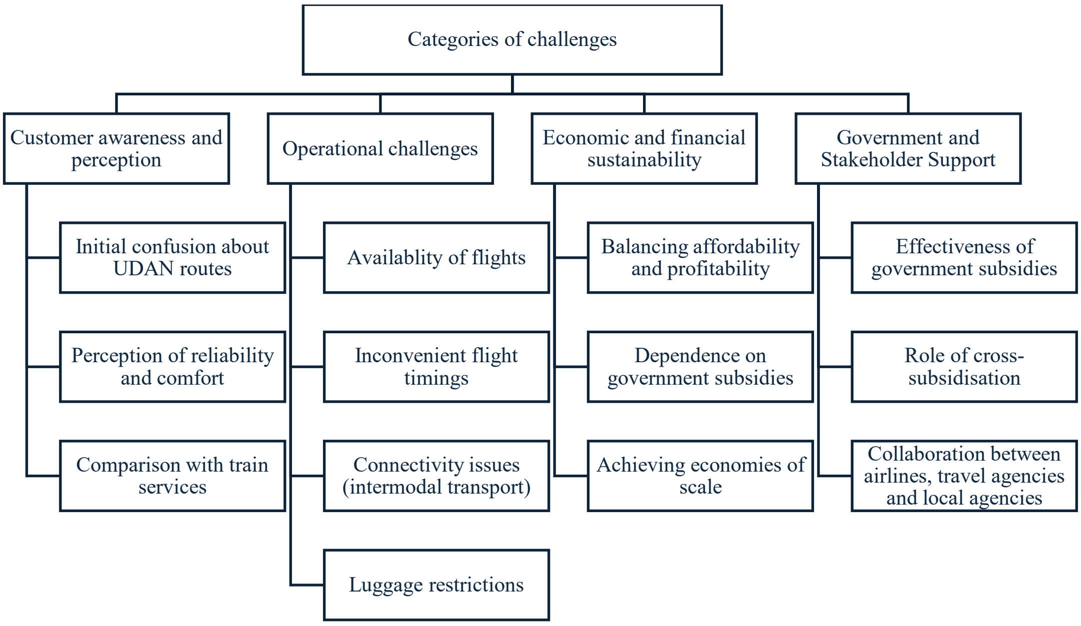
Prioritising challenges of travel agents providing ticketing services to passengers under the UDAN scheme.

Challenges category	Indicators	Definition
Challenges in the UDAN scheme (Travel agents' perspective)	*Customer awareness and perception*	Awareness among passengers about regional connectivity schemes
	Operational challenges	Airlines facing difficulties due to inadequate airport infrastructure
	Economic and financial sustainability	Assessing the scheme's sustainability in the market
	Government and stakeholder support	Challenges in achieving collaboration among stakeholders for the success of the scheme

Q1. Which of the following ***challenges*** is ***relatively more important*** when considering the challenges from the travel agents' perspective in participating in the UDAN scheme and continuing its implementation?

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Customer awareness and perception																		Operational challenges
																		Economic and financial sustainability
																		Government and stakeholder support
Operational challenges																		Economic and financial sustainability
																		Government and stakeholder support
Economic and financial sustainability																		Government and stakeholder support

Section C: Prioritising the challenges within different categories



Challenges category	Indicators	Definition
Customer awareness and perception	*Initial confusion about UDAN routes*	Lack of awareness among customers/passengers regarding the scheme's objectives
	Perception of reliability and comfort	Customer satisfaction with key scheme aspects like flight timing, luggage handling, and last-mile connectivity.
	Comparison with train services	Impact of alternative transportation services like trains on UDAN scheme
Operational challenges	*Availability of flights*	Limited availability of flights to specific regions or routes.
	Inconvenient flight timings	Timings not preferred by passengers, causing discomfort
	Connectivity issues (intermodal transport)	Challenges faced by passengers in reaching city centres or last-mile destinations due to limited availability of connecting trains, buses, or taxis.
	Luggage restrictions	Limitations on luggage allowance

Economic and financial sustainability	*Balancing affordability and profitability*	Balancing passenger affordability with airline profitability on RCS routes.
	Dependence on government subsidies	Effectiveness and duration of subsidies benefiting airlines and passengers
	Achieving economies of scale	Demand and sustainability of the business, especially with RCS routes from Travel agents' perspective
Government and stakeholder support	*Effectiveness of government subsidies*	significance of government subsidies for airlines and their impact on travel businesses
	Role of cross-subsidisation	Effectiveness and sustainability of cross-subsidisation by airlines to support the scheme and travel businesses
	Collaboration between airlines, travel agencies and local agencies	Significance of collaboration between airlines, travel agencies, and regulators

Q2. Which of the following ***customer awareness and perception challenge*** is ***relatively more significant*** for travel agents' participating in the UDAN scheme, particularly in facilitating its implementation? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Initial confusion about UDAN routes																		Perception of reliability and comfort
																		Comparison with train services
Perception of reliability and comfort																		Comparison with train services

Q3. Which of the following ***operational challenge*** is ***relatively more significant*** for travel agents' participating in the UDAN scheme, particularly in facilitating its implementation? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Availability of flights																		Inconvenient flight timings

																		Connectivity issues (intermodal transport)
																		Luggage restrictions
Inconvenient flight timings																		Connectivity issues (intermodal transport)
																		Luggage restrictions
Connectivity issues (intermodal transport)																		Luggage restrictions

Q4. Which of the following ***economic and financial sustainability challenge*** is ***relatively more significant*** for travel agents' participating in the UDAN scheme, particularly in facilitating its implementation? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Balancing affordability and profitability																		Dependence on government subsidies
																		Achieving economies of scale
Dependence on government subsidies																		Achieving economies of scale

Q5. Which of the following ***stakeholder challenge*** is ***relatively more significant*** for travel agents' participating in the UDAN scheme, particularly in facilitating its implementation? (please √ to indicate your answer)

Indicator A	Extremely agree		Very strongly agree		Strongly agree		Slightly agree		Equal	Slightly agree		Strongly agree		Very strongly agree		Extremely agree		Indicator B
Scale	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scale
Effectiveness of government subsidies																		Role of cross-subsidisation
																		Collaboration between airlines, travel agencies, and local governments
Role of cross-subsidisation																		Collaboration between airlines, travel agencies, and local governments

Appendix B – Invitation letter to participants for exploratory interviews

Dear Participant,

My name is Ajai Jayathilakan, a PhD candidate at Massey University, New Zealand. I am conducting research on India's regional connectivity scheme-UDAN, focusing on stakeholder perspectives regarding the challenges in its implementation and continuation.

I am inviting aviation stakeholders to share insights on how the scheme impacts operations and policy. Your expertise is invaluable to understanding the operational and strategic hurdles that influence the scheme's effectiveness and sustainability.

Participation involves a brief interview (25–30 minutes) at your convenience via Zoom, Microsoft Teams, or a preferred platform. All responses will remain confidential and used solely for academic purposes. Participation is voluntary, and you may withdraw at any time without consequence.

If you have questions or require more information, please contact me at a.jayathilakan@massey.ac.nz. For concerns about the ethical conduct of this study, you may reach out to Professor Tracy Riley, Acting Chair, Research Ethics Chairs' Committee, at humanethics@massey.ac.nz.

Thank you for considering this request. I appreciate your time and insights.

Warm regards,

Ajai Jayathilakan
PhD Candidate, School of Aviation
Massey University, New Zealand
Email: a.jayathilakan@massey.ac.nz
Tel: +64 6 951 8647

Appendix C – Invitation letter to participants for participating in online surveys

Dear Participant,

My name is Ajai Jayathilakan, and I am a PhD candidate at Massey University, New Zealand. I am conducting research on India's regional connectivity scheme, UDAN, with a focus on aviation stakeholder perspectives regarding challenges in its implementation and long-term sustainability.

As part of this study, I am inviting aviation stakeholders, including professionals from airlines, airports, regulatory bodies, and travel agencies, to participate in a short online survey aimed at understanding operational and policy-related challenges. Your insights are vital to developing a deeper understanding of the scheme's practical implications.

The survey uses a bipolar scale format (e.g., *strongly disagree* to *strongly agree*) to capture nuanced perceptions. It will take approximately 20 minutes to complete and is hosted securely on Qualtrics. You will receive a link tailored to your stakeholder category. All responses will be kept strictly confidential and used solely for academic purposes. Your identity is optional, and participation is entirely voluntary, you may withdraw at any time without consequence.

For any questions, please contact me at a.jayathilakan@massey.ac.nz. For ethical concerns, you may reach Professor Tracy Riley, Acting Chair, Research Ethics Chairs' Committee, at humanethics@massey.ac.nz.

Thank you for considering this request. Your time and expertise are greatly appreciated.

Warm regards,

Ajai Jayathilakan
PhD Candidate, School of Aviation
Massey University, New Zealand
Email: a.jayathilakan@massey.ac.nz
Tel: +64 6 951 8647

Appendix D – Consolidated local and global weights and rankings of challenges

Stakeholder	Main Criteria	CR	Sub criteria	Weights (%)	Rank	MC Weights	MC Weight Percentage	Local weight Percentage	Global weight	Ranking
Airlines	Infrastructure and connectivity	0.06	Urban integration and accessibility	54.9	1	28.6	0.286	0.549	0.157	1
	Revenue constraints and profitability	0.01	Load factor and seat occupancy	57.2	1	21.3	0.213	0.572	0.122	2
	Government support and subsidies	0	Financial incentives and concession	36.2	2	25.9	0.259	0.362	0.094	3
	Government support and subsidies	0	State government support	35.6	1	25.9	0.259	0.356	0.092	4
	Aircraft and operational challenges	0.12	Availability of Suitable aircraft	58.1	1	13.5	0.135	0.581	0.078	5
	Infrastructure and connectivity	0.06	Intermodal connectivity	25.9	2	28.6	0.286	0.259	0.074	6
	Government support and subsidies	0	Viability GAP Funding	28.2	3	25.9	0.259	0.282	0.073	7
	Infrastructure and connectivity	0.06	Development of Airport Infrastructure	19.1	3	28.6	0.286	0.191	0.055	8
	Revenue constraints and profitability	0.01	Pricing strategies	21.5	2	21.3	0.213	0.215	0.046	9
	Revenue constraints and profitability	0.01	Cost management	21.2	3	21.3	0.213	0.212	0.045	10
	Future prospects and market demand	0	Readiness of support system (e.g., ATC)	40.8	1	10.7	0.107	0.408	0.044	11
	Future prospects and market demand	0	Market demand and growth	33.6	2	10.7	0.107	0.336	0.036	12
	Aircraft and operational challenges	0.12	Maintenance, repair and overhauling facility	24.5	2	13.5	0.135	0.245	0.033	13
	Future prospects and market demand	0	Invest in regional aviation	25.6	3	10.7	0.107	0.256	0.027	14
	Aircraft and operational challenges	0.12	Operational costs	17.4	3	13.5	0.135	0.174	0.023	15
Airports	Infrastructure and operational challenges	0.03	Inadequate infrastructure and connectivity	66.9	1	47.7	0.477	0.669	0.319	1
	Financial challenges	0.06	Lack of revenue from RCS flights	60	1	31.1	0.311	0.6	0.187	2
	Financial challenges	0.06	Insufficient subsidies and support	28.9	2	31.1	0.311	0.289	0.09	3
	Infrastructure and operational challenges	0.03	Security and safety concerns	18.2	2	47.7	0.477	0.182	0.087	4
	Stakeholder collaboration and communication challenges	0.11	Urban integration and accessibility (last mile connectivity etc.)	59.6	1	12	0.12	0.596	0.072	5
	Infrastructure and operational challenges	0.03	Environmental and land acquisition issues	14.9	3	47.7	0.477	0.149	0.071	6

	Regulatory and policy challenges	0	Bureaucratic hurdles and unclear responsibilities	52.4	1	9.2	0.092	0.524	0.048	7
	Stakeholder collaboration and communication challenges	0.11	Poor stakeholder cooperation	31.4	2	12	0.12	0.314	0.038	8
	Financial challenges	0.06	High operational cost	11.1	3	31.1	0.311	0.111	0.035	9
	Regulatory and policy challenges	0	Insufficient support for airports	31.1	2	9.2	0.092	0.311	0.029	10
	Regulatory and policy challenges	0	Regulatory constraints affecting operations	16.6	3	9.2	0.092	0.166	0.015	11
	Stakeholder collaboration and communication challenges	0.11	Lack of clear communication and transparency	9	3	12	0.12	0.09	0.011	12
Regulator	Infrastructure challenges	0.025	Challenges in asset readiness for operations	46.8	1	43.3	0.433	0.468	0.203	1
	Financial challenges	0.009	Absence of revenue generation	50.9	1	28.3	0.283	0.509	0.144	2
	Infrastructure challenges	0.025	Slow-paced infrastructure creation	31.7	2	43.3	0.433	0.317	0.137	3
	Airline participation challenges	0.107	Airlines Opting Out and Reasons for Discontinuation	36.4	1	23.5	0.235	0.364	0.086	4
	Financial challenges	0.009	Operational challenges without commercial flights	27.4	2	28.3	0.283	0.274	0.078	5
	Airline participation challenges	0.107	Continuation of Operations Beyond Initial Three-Year Period	32.6	2	23.5	0.235	0.326	0.077	6
	Infrastructure challenges	0.025	Land acquisition and regulatory compliance issues	12.5	3	43.3	0.433	0.125	0.054	7
	Airline participation challenges	0.107	Competition on Assigned Routes	17.9	3	23.5	0.235	0.179	0.042	8
	Financial challenges	0.009	High ATC costs for Airport operators	13.9	3	28.3	0.283	0.139	0.039	9
	Infrastructure challenges	0.025	State government's limitations in regulatory compliance	9	4	43.3	0.433	0.09	0.039	10
	Airline participation challenges	0.107	Maturity of Routes into Commercial Viability	13.1	4	23.5	0.235	0.131	0.031	11
	Regulatory challenges	0.073	Lack of a well-developed ecosystem for small airlines	59.8	1	5	0.05	0.598	0.03	12
	Financial challenges	0.009	Monopoly of Air Traffic Management by AAI	7.7	4	28.3	0.283	0.077	0.022	13
	Regulatory challenges	0.073	Pace of infrastructure creation (CAPEX)	21.6	2	5	0.05	0.216	0.011	14
	Regulatory challenges	0.073	Role of regulators in addressing challenges	11.3	3	5	0.05	0.113	0.006	15
	Regulatory challenges	0.073	Policy uncertainty and regulatory clarity	7.4	4	5	0.05	0.074	0.004	16

Travel agents	Government and stakeholder support	0.073	Collaboration between Airlines, Travel Agencies, and Local Governments	39.6	2	35.8	0.358	0.396	0.142	1
	Government and stakeholder support	0.073	Role of Cross-Subsidisation	39.3	1	35.8	0.358	0.393	0.141	2
	Customer awareness and perception challenge	0.027	Perception of reliability and comfort	45.8	1	24.9	0.249	0.458	0.114	3
	Operational challenges	0.045	Connectivity Issues (Intermodal Transport)	49.2	1	17.6	0.176	0.492	0.087	4
	Economic and Financial Sustainability	0.092	Dependence on Government Subsidies	38.4	1	21.6	0.216	0.384	0.083	5
	Customer awareness and perception challenge	0.027	Comparison with train services	30.8	2	24.9	0.249	0.308	0.077	6
	Government and stakeholder support	0.073	Effectiveness of Subsidies	21.1	3	35.8	0.358	0.211	0.076	7
	Economic and Financial Sustainability	0.092	Achieving Economies of Scale	31.3	2	21.6	0.216	0.313	0.068	8
	Economic and Financial Sustainability	0.092	Balancing Affordability and Profitability	30.3	3	21.6	0.216	0.303	0.065	9
	Customer awareness and perception challenge	0.027	Initial confusion about UDAN routes	23.4	3	24.9	0.249	0.234	0.058	10
	Operational challenges	0.045	Inconvenient Flight Timings	26.1	2	17.6	0.176	0.261	0.046	11
	Operational challenges	0.045	Availability of flights	19.1	3	17.6	0.176	0.191	0.034	12
	Operational challenges	0.045	Luggage Restrictions	5.6	4	17.6	0.176	0.056	0.01	13