Adapting to uncertainty: Black swans, VUCA challenges and airport resilience strategies

Noel Hiney , Marina Efthymiou , Edgar Morgenroth

Dublin City University, Business School, Glasnevin, Dublin 9, Ireland

ARTICLE INFO

ABSTRACT

Over the past 50 years, air travel and airport passenger numbers have consistently grown, despite setbacks from crises like oil shocks, terrorism and the COVID-19 pandemic. Post-pandemic passenger trends demonstrated the resilience of aviation and airports when recovering from the effects of major crises, notwithstanding the increased future uncertainty caused by geopolitical events since then. Through a combination of airport passenger performance analysis from 2019 to 2023, an airport manager survey undertaken in 2022 and an assessment of events and trends during this period, as reported in the literature and contemporaneously through news and information channels, this paper assesses factors affecting airports during volatile, uncertain, complex and ambiguous (VUCA) periods, focusing on post-pandemic passenger trends and current challenges. It also explores how airports can enhance resilience through improved processes, efficiency, and stronger stakeholder relationships. We found that smaller airports, in particular, will face revenue pressures, growing competition, and increased dependence on non-aeronautical revenue. State aid, increasingly tied to decarbonisation and digitalisation, will also become more challenging to secure. Linking empirical research findings with actionable strategies to enhance airport resilience and address these issues, we introduce the VUCAIR framework, a strategic model designed to help airports anticipate and respond effectively to ongoing VUCA conditions in the global aviation landscape.

1. Introduction

The aviation sector represents one of the most interconnected global industries, underpinning international trade, economic activity and social engagement, with airports serving as critical nodes facilitating these connections. Over recent decades, air transport has consistently grown and demonstrated considerable resilience amid recurrent disruptions such as oil shocks, terrorism, financial downturns, and pandemics, notably COVID-19. Furthermore, the increasing frequency and complexity of these disruptions, including emerging geopolitical tensions and economic shocks arising therefrom has intensified the levels of volatility, uncertainty, complexity, and ambiguity (VUCA) experienced by airports. Consequently, airports' capability to maintain robust operations and recovery has come under increased scrutiny, highlighting resilience as a critical operational imperative and underscoring the urgent need for airports to become strategically agile and adaptive in anticipating and managing emerging uncertainties. In this paper, we define airport resilience as "the ability of airports to respond and adapt effectively to significant unplanned disruptions or events, thus protecting airport operations and business activities".

This paper investigates the dynamics of post-pandemic passenger recovery and airport resilience specifically within the context of the VUCA conditions described above. The COVID-19 pandemic resulted in passenger volumes collapsing dramatically due to travel restrictions and government health measures. Despite a faster-than-anticipated overall resurgence, passenger recovery has been uneven, influenced notably by airport characteristics such as size, geographic location, and reliance on specific carrier types like low-cost airlines (LCCs). Airports managing between one and ten million passengers annually have demonstrated a stronger rate of recovery, whereas those impacted by geopolitical factors, such as airports affected by the Russian invasion of Ukraine, significantly underperformed (ACI Europe, 2024). Given the expected increase in and intensity of VUCA-characterised disruptions, there is a clear need for targeted strategic frameworks explicitly tailored to airports, enabling them to effectively anticipate, respond, and adapt to unpredictable and rapidly evolving scenarios.

Existing such literature acknowledges airport resilience as essential, however gaps remain regarding frameworks that integrate stakeholder management and agile/adaptable strategies tailored specifically for airports operating under VUCA conditions. Current models do not adequately address the complexities of airport-specific activity or how distinct airport characteristics influence their (and their stakeholders') resilience and recovery trajectories (Bloch et al., 2021; Kivits and Sawang, 2021). While prior discussions have briefly explored the

relevance of VUCA frameworks in aviation contexts, empirical research explicitly examining airport operations under these conditions remains limited. Thus, there is a clear opportunity, informed by theory, to develop and propose a practical framework which bridge factors affecting resilience with actionable strategies specific to airports.

This paper addresses these critical gaps through empirical and theoretical contributions. It assesses airport passenger recovery trends from 2019 to 2023, explicitly highlighting variations influenced by characteristics including seasonality and the presence of Public Service Obligation (PSO) routes at specific airports. Additionally, the paper investigates stakeholder priorities and strategic responses identified through a targeted survey of airport managers conducted in 2022, providing practical insights into effective stakeholder management activity. The primary contribution of this research is the introduction of the VUCAIR Framework—a strategic, empirically-grounded tool designed specifically for airport managers and policymakers. VUCAIR aligns specific resilience challenges—geopolitical instability, financial volatility, stakeholder complexity, and ambiguous regulatory environments—with actionable response strategies, thus offering structured guidance for anticipating and effectively managing airport disruptions under VUCA conditions. The model considers and is informed by quantitative passenger data analysis, qualitative manager insights, and a comprehensive literature review, effectively linking resilience related theory with practical applications for airport organisations.

The remainder of this paper is structured as follows: Section 2 outlines the mixed-methods research methodology, comprising quantitative passenger data analysis (*ACI* database 2019–2023), qualitative insights from the airport manager survey, and literature assessment relevant to airport activity and resilience. Section 3 provides a literature review, positioning airport resilience within recent global disruptions, also referring to existing VUCA frameworks. Sections 4 and 5 present research findings, analysing passenger recovery patterns in relation to airport characteristics and highlighting stakeholder perspectives on resilience challenges and strategies. Section 6 introduces the VUCAIR Framework, demonstrating its practical application for airport resilience. Finally, Section 7 discusses the practical implications of the research, summarises key contributions, acknowledges limitations, and suggests opportunities for future research, tailored specifically to factors affecting resilience in the airport sector.

2. Research methodology

This paper has used a multi-methods research approach to assess airport activity and performance during the post-COVID-19 pandemic period. Research undertaken combines passenger performance analysis, a structured stakeholder survey and a critical review of current literature and industry reportage, creating a robust basis for understanding airport resilience in volatile, uncertain, complex, and ambiguous (VUCA) conditions. This approach ensures comprehensive coverage of the research objectives, informing key findings.

Airport Passenger Data Analysis (2019–2023). The paper comprises a quantitative analysis of European airport passenger performance from 2019 to 2023. This dataset includes detailed passenger, cargo, and movement data. Specifically, a European airport data subset (910 airports) is used to examine post-pandemic recovery trends and to identify key performance patterns. Analytical focus areas include passenger volume trends and how these were impacted by airport size, seasonality, location, the influence of Public Service Obligation (PSO) routes, and airport ownership type. The latter two categories were chosen based on their topic relevance and specific external data availability, being PSO route information (European Commission, 2023) and airport ownership details (*ACI* Europe, 2016),rather than being selected in an arbitrary manner. This approach facilitated an assessment of how these external variables might have influenced air passenger performance.

Airport Manager Survey 2022. Complementing the analysis of airport passenger performance, an N survey of airport managers was

undertaken in 2022 to gather expert insights into stakeholder priorities, strategies, and perceived threats and opportunities during the pandemic recovery period. This timing ensured that the survey captured key points with respect to airport vulnerability and uncertainty, given the external environment they were experiencing at that time, e.g. large airport capacity issues and Russian invasion of Ukraine. The survey contained twenty-five questions, including three open-ended items to capture richer, qualitative stakeholder perspectives. Responses were collected from twenty-seven experienced airport managers across business and operational roles, mainly within Europe, providing a balanced view across different airport types and sizes. Survey data is critically assessed to identify post-pandemic movement in stakeholder priorities and interactions. The survey also identified key threats as reported by airport managers, and it also explored opportunities arising from digitalisation, government support, and the resilience of the aviation industry. This dual focus provided a comprehensive overview of the operational landscape for airports.

Literature Review. To contextualise passenger data and airport manager survey findings within the broader post-pandemic and geopolitical context, an extensive review of mostly post-pandemic literature and industry reports is conducted. This research includes an assessment of aviation industry reports, policy documents, and relevant media reportage from recognised and credible sources. Particular attention is given to evolving airport strategies in digitalisation, financial resilience, and sustainability, drawing on contemporary sources such as EUROCONTROL, Airports Council International (*ACI*), the European Commission, and recent scholarly work.

Insights from these complementary research components informs development of the VUCAIR framework, an original, practical and strategic tool, specifically designed to help airports manage VUCA-related challenges. This framework (Section 6) facilitates a structured examination by airport managers of key airport challenges. It encompasses factors such as organisational adaptability, sustainability and technological innovation, providing a basis for airport actions.

Using this research approach, the study provides actionable insights, and a framework designed to help airport operators and policymakers navigate the complexities of the current aviation landscape, contributing to improved strategic airport planning and operational effectiveness in the face of ongoing challenges.

3. Literature review

Airport resilience has been defined in this paper as "the ability of airports to respond and adapt effectively to significant unplanned disruptions or events, thus protecting airport operations and business activities". This section of the paper explores the components (some interconnected) of recovery-related airport activities and processes (including stakeholder roles and strategic frameworks) essential for challenging (VUCA) times. These factors are examined by reviewing post-pandemic events, airport recovery activities (including stakeholder management), and adaptive strategic frameworks, setting the stage for the further analysis, through primary research, the activity methodologies outlined above. Since 2020, the academic literature on COVID-19′s impact on air transport has grown substantially, addressing immediate operational impacts, airport resilience, and recovery strategies (e.g. Suau-Sanchez et al., 2020; Budd et al., 2020; Huang et al., 2021; Janic, 2022; Sun et al., 2024). These contributions and those referred to below position the authors' research within this body of work and build on it by presenting new research and identifying gaps related to airport management of resilience and recovery activities.

The COVID-19 pandemic resulted in unprecedented operational and economic disruptions to airports, testing levels of resilience limits. Existing literature and studies illustrate varied airport responses to crises, highlighting strategies such as diversification, cost control, and innovation. Collaboration and airport network-level resilience assessments have been advocated for, rather than individual airport activity.

Mor recent insights suggest that agile stakeholder management and diversified revenue streams can significantly enhance airport resilience and recovery success. Although VUCA models have traditionally been explored across sectors, recent aviation-focused studies emphasise the use of structured frameworks to manage volatility and ambiguity. These topics are now explored in greater detail.

3.1. Airports and a volatile post-pandemic period

3.1.1. Airport post-pandemic performance

Policymakers and practitioners agree that regional airports comprise a core component of Europe's transport network, providing affordable connectivity and social cohesion (European Commission, 2023) and accounting for almost half of air passenger travel within Europe. ACI initially estimated that almost 200 European airports were at risk of closure due to the pandemic effect (Posaner and Nostlinger, 2020), although it was not expected that any would be permanently closed during the pandemic period itself.

Regional airports were also core to post-pandemic economic recovery across the continent, especially during the time when long-haul markets remained closed (ACI Europe, 2023a). However, they faced significant operational and financial challenges as revenue collapsed while fixed costs, including capital expenses, remained high. The relationship between airport size and operational costs is complex due to varying revenue levels despite similar infrastructure costs. For example, 62 % of smaller airports handled ten or fewer flights daily in 2022, resulting in high per-passenger costs of €13 to €17 (ACI Europe, 2023b).

Notwithstanding horizontal and vertical state support provided to airports during the pandemic (European Commission, 2020), significant financial challenges remained. Serrano and Kazda (2020) highlighted a number of strategies to adapt to fluctuating demand, including revenue generation, cost control, and innovative practices. Even as aviation began to emerge from the effects of the pandemic, further challenges arose such as staff shortages in flight crew, ground handlers and security staff creating additional operational pressures (Sobieralski and Hubbard, 2023; Tang et al., 2023).

Another challenge highlighted for regional airports, (in addition to the cost to airports of keenly negotiated traffic contracts more favourable to airlines, was the lower level of non-aeronautical revenue achieved at smaller airports relative to larger airports at the outset of the period under review (Fig. 1).

This revenue gap is exacerbated by a growing dependence on low-cost carriers, which have expanded faster than other airline types since the pandemic. By 2022, low-cost carriers accounted for 51 % of

seats at regional airports, up from 43 % in 2019 (ACI Europe, 2023b). Increased reliance on these carriers has intensified competition, pushing smaller airports to increase their focus on non-aeronautical revenue and, potentially, their increased dependence on State aid.

Airport competition remained intense during 2022 and 2023, with Airports Council International contending that almost 800 European airports were competing for the business from a limited pool of agile, 'footloose' airlines (ACI Europe, 2023b). Higher ticket prices, driven by strong demand and reduced aircraft availability, benefited airlines more than airports, prompting airport representatives to call for a re-examination of the economic regulatory balance between airports and airlines (Georgiadis, 2023). Lemonnier (2021) considered the effects of distinct types of aviation sector concentrations on the negotiating power of airlines versus airports; identifying regulatory shortcomings of the Airport Charges Directive (2009/12/EC) which might favour airlines.

Eccles and Hernandez-Morales (2020) highlighted a 'coronavirus-induced nosedive' for many of Europe's regional airports, recognising that the pandemic was making an already tough situation worse. As the industry moved into a further uncertain period following the Russian invasion of Ukraine, some airports were already reviewing their business models (Colak et al., 2023) to increase their resilience to future systemic shocks, through a focus on cost-effectiveness and minimisation; diversification of revenue streams and intensified commercial activities; enhanced digitalisation and operational efficiency, and sustainability. The shift toward digital channels has also fuelled e-commerce and cargo growth, creating new revenue opportunities for smaller airports with a larger proportion of cargo traffic (Florido-Benitez, 2023).

Evolving attitudes toward the pandemic and improvements in mitigation strategies led to stronger expectations for air travel recovery since 2022 (Rangaswamy et al., 2022).

3.1.2. Reviewing airport business contingency planning

Five significant "megatrends" for airport managers and planners facing challenging times were identified by Oliver Wyman (Naswas, 2023): "achieving net zero, technological innovation, intermodal connectivity, workforce evolution, and the transformation of passenger experience". Additionally, the need for strengthened coordination in business continuity and resilience highlighted the importance of updating contingency plans and risk frameworks. These actions were presented as essential to addressing operational and economic challenges, ensuring aviation safety, and maintaining functionality during future crises, thereby mitigating socioeconomic impacts and preserving the economic viability of the airport system (Romig, 2021; Hiney et al., 2024).

A collaborative approach between airports and stakeholders was increasingly recognised as crucial in minimising the adverse effects of future disruptions (Bloch et al., 2021). Such collaboration would focus on achieving stakeholder consensus, which Kivits and Sawang (2021) highlighted as essential for effective management in aviation and other infrastructure sectors. The importance of international coordination for a global recovery of air travel was also emphasised by EUROCONTROL (2022), alongside Rangaswamy et al. (2022) and Hiney et al. (2023). Environmental initiatives such as the Emissions Trading Scheme and Single European Sky further demonstrated the interdependence of reforms within aviation (Efthymiou and Papatheodorou, 2019), while Robinson (2020) emphasised the value of cross-sector collaboration in driving innovation and transformation in response to industry challenges.

Environmental sustainability also emerged as a priority for airports, particularly in the context of aviation's commitment to achieving net zero by 2050 (Jensen et al., 2023). Key initiatives suggested included sourcing low-emission electricity, enhancing energy efficiency, and electrifying ground support and gate equipment (Greer et al., 2020). Regional airports, especially those serving commuter flights, are likely to be the first to accommodate electric or hybrid aircraft. However,

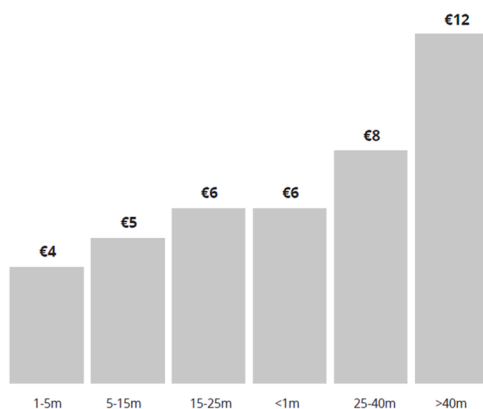**Non-Aeronautical Airport Revenue Per Passenger (2019)**

Fig. 1. Non-Aeronautical Airport Revenue Per Passenger (2019).
Source: European Regional Airports: Sustainably Connecting People, Places and Products (ACI, 2023).

financial support would likely to be necessary for infrastructure upgrades to support these changes, while future initiatives were expected to link environmental efforts more closely with operational outcomes, with smaller airports in remote and island regions needing to carefully balance socioeconomic and environmental goals (*ACI* Europe, 2023b).

The impact of European Commission guidelines on State aid and policies supporting airline and airport operators is particularly relevant for smaller airports (Grimme et al., 2018). The increase in vertical (industry-specific) State aid led to more legal challenges, some of which argued that such aid unfairly benefited national carriers (Deasy, 2021). Following a stakeholder consultation in 2022, the European Commission extended its Airport State Aid framework until April 2027 (European Commission, 2023). However, the long-term survivability of financially unsustainable airports remained uncertain.

3.2. Airport resilience and post-pandemic recovery

COVID-19 significantly disrupted airport operations worldwide, adversely affecting operational and economic airport measures. The pandemic also highlighted gaps in airports' preparedness for sustained global disruptions. extensive vulnerabilities in maintaining airport planning and performance during this period, Janic (2022) found that major airports experienced material declines in resilience and robustness. Arora et al. (2021) further highlighted the unprecedented scale of this disruption as considered at that time, noting severe economic impacts, workforce reductions, and challenges in effectively integrating lessons from past health crises (e.g. SARS) into post-pandemic aviation procedures (e.g. testing).

Recent research on airport resilience has considered airports' capacities to withstand and recover from disruptions through enhanced operations and greater resilience. Huang et al. (2021) suggested actionable insights for policymakers, while Wandelt et al. (2025) proposed an index-based measurement approach, using airside and ground infrastructure measures, to assess the impact of airport disruptions on global air transport. Furthermore, network-level assessments by Guo et al. (2021a, 2021b) and Wang et al. (2022) concluded that resilience is not just measured at individual airport level but is also influenced by changes in air connectivity and by external factors such as the effect of airport-impacting government policies. Differences in the pace of recovery across different global regions were also identified. These were partly influenced by policy responses, for example differing government restrictions on travel, and strategic management decisions.

Guo et al. (2023) indicate that China's disciplined pandemic response facilitated a quicker rebound of its domestic air transport system compared to Europe and the United States where uneven and prolonged policy restrictions may have extended passenger recovery times. However its more enduring restriction on international travel meant that the recovery in long-haul traffic to and from Asian regions lagged that of Europe and the United States (Graham et al., 2023). Sun, Zheng and Zhang (2024) emphasised the need for agile and adaptive management within airports, highlighting the need for a diversification of airport revenue streams and enhanced airport stakeholder coordination. Finally, Sun et al. (2022) highlighted workforce training and improved technology as key building blocks to achieve greater airport resilience and preparedness for future disruption/dislocation.

To further strengthen their post-pandemic performance and resilience, airports increasingly focused on achieving flexible, well-managed cost bases and expanding non-aeronautical revenue, including property development, while maintaining a safe passenger experience (Colak et al., 2023; Lennon, 2022).

3.3. A more volatile aviation environment

The impact of globalisation, the digital economy, post-pandemic developments and innovation activities were expected to result in disruption of the air travel sector (Amoah et al., 2021; Robinson, 2020).

While modern technologies provided for increased levels of innovation, they could also challenge traditional aviation operations and services. Lennon (2022) noted the pressure on stakeholders to achieve transformation by transitioning to contactless and digital engagement methods, offering passengers a more personalised and holistic airport user experience (Bolton, 2020; Tuchen et al., 2020).

An increasingly competitive aviation and airport market and the uncertain effects of external shock events are two factors which gave rise to a more volatile air transport environment during the research period. While effective planning and diversification strategies can improve airport strategic responsiveness and financial performance (de Wit, 2022), the unique impact of events such as the COVID-19 pandemic brought disruption beyond any planning expectations. This uncertain state contributed to the need to explore how airports might plan for and respond to such exceptional 'shock' events. In this new normal environment, change was seen as a key constant, planning and forecasting was more uncertain and regulatory changes would occur ever more frequently (Robinson, 2020). Furthermore, the increasing risk of black swan events, which are difficult to predict (de Wit, 2022; Liu, 2023), would require airports to exercise caution and anticipate future developments, as new information and developments could limit the effectiveness and/or validity of earlier responses.

In such uncertain environments, the term 'VUCA' has become a pivotal framework for understanding the challenges faced by various industries, including the aviation sector. VUCA is a contemporary strategic model which can help organisations categorise and better understand the *volatile, uncertain, complex and ambiguous* challenges they are likely to encounter during challenging times. The VUCA framework has been used by scholars studying leadership and management (Akkaya and Sever, 2022; Ramakrishnan, 2021; Sinha and Sinha, 2020), COVID-19 pandemic impacts (Dima et al., 2021; Worley and Jules, 2020), the automotive industry (Mayer and Wilke, 2022), and tourism (Lubowiecki-Vikuk and Sousa, 2021; Major and Clarke, 2021).

The challenges identified above establish that the post-pandemic airport environment is one characterised by VUCA (Volatile, Uncertain, Complex, Ambiguous) elements. Indeed, the VUCA model has been alluded to in aviation literature across a range of topics, including *developing resilience when responding to disruption* (Kim et al., 2022); *safety risk management* (Basimakopoulou et al., 2022); *organisational factors and lean management* (Helmold et al., 2022); *sustainable aviation* (Muller et al., 2022); *employee resilience and satisfaction* (Douglas, 2022) and *the airport user experience* (Tuchen et al., 2020).

Airport use of the VUCA framework as a change management and scenario planning model to help managers navigate a more uncertain world is explored further in this paper and a dedicated airport framework, VUCAIR, is proposed.

4. Research findings

4.1. Assessment of European airport passenger volumes and trends 2019–2023

This section of the paper explores the post-COVID-19 airport passenger recovery trajectory by examining volumes and trends across 910 European airports from the beginning of the last full year before the pandemic (2019) to the end of 2023, providing critical insights into the performance of various airport types and characteristics. Using comprehensive monthly and annual data from Airports Council International's *Intelligence Hub* database and overlaying figures/insights from other sources including European Public Service Obligation (PSO) route information, the authors' analysis aims to provide readers with a nuanced understanding of how passenger activity evolved during the immediate post-pandemic period.

The COVID-19 pandemic significantly disrupted global air travel, with passenger volumes falling to significantly during 2020, due to government-imposed travel restrictions. However, a strong recovery in

these levels was noted in subsequent years, driven first by the easing, then removal, of these travel restrictions, and satisfaction of pent-up travel demand. By the end of 2023, European airports reported passenger numbers nearing 94 % of pre-pandemic levels, underscoring the resilience of the aviation sector despite the challenges provided by this and previous major events such as geopolitical conflicts and macroeconomic pressures.

The post-pandemic era was marked by a strong and sustained resurgence in air travel (Figs. 2, 3 and 4), with most markets achieving over 80 % of their pre-pandemic passenger levels. This recovery, however, has been uneven across regions and airport types, influenced by factors such as geopolitical tensions and regional travel dynamics. Countries below the 80 % threshold were generally those affected by the Russian invasion of Ukraine. The strongest recovery was found in airports processing between one and ten million passengers per annum.

Fig. 3 has plotted passenger numbers from the baseline pre-pandemic year (2019) against 2023 vol as a percentage. This approach was selected to clearly illustrate both the relative size of each country's aviation market (vertical axis) and the extent of its passenger recovery (horizontal axis). Fig. 4 highlights country by country percentage changes, again expressing 2023 performance against 2019 vol. This approach offered a high-level insight into market size and postpandemic recovery performance.

Many smaller airports in popular tourist destinations, such as Greece and Spain, reached or exceeded pre-pandemic passenger levels by the end of 2022. Tourism-driven markets led the recovery, with Greece and Portugal exceeding 90 % of 2019 vol, and Spain, Italy, Türkiye, and France surpassing 80 %. This data confirms the stronger recovery of southern European markets, relative to other regions. In addition to location, factors including airport size, route mix, and geopolitical events. Ukraine's air traffic was shut down due to Russia's invasion of Ukraine, impacted trends in 2022 and 2023, while Finland's recovery lagged other locations due to reduced Asian demand and Russian airspace restrictions, which affected Helsinki airport's mini-hub routes to Asia. Eastern Europe's overall recovery was weaker, sustained largely by Russia's domestic air market at lower volumes.

Further analysis below compares 2019 and 2023 European airport passenger performance, focusing on factors such as Public Service Obligation (PSO) routes at smaller airports, coastal location, traffic seasonality, and airport ownership. These variables were selected specifically for their relevance to airport recovery and resilience, as well as the availability of secondary data. Findings generally indicate that, except for ownership type, these characteristics were associated with quicker traffic recovery, with many airports returning to or exceeding 2019 passenger levels by 2023. The limited availability of financial data restricts definitive conclusions on these additional influences, however.

For example, some locations may also have benefited from increased State aid or new airline agreements,

Airports with fewer than five million passengers per annum were selected because a focus of this part of the analysis was to evaluate the impact of the presence of Public Service Obligation (PSO) routes, versus their absence, at smaller/regional airports rather than larger ones, where their impact on overall traffic volumes would be less significant.

PSO Finding: 72 airports in the *ACI* database operated PSO air routes in 2023. Airports with under five million annual passengers in 2019 showed stronger 2023 recovery if they operated such routes, compared to similar-sized airports without them. These airports also saw a greater passenger increase from 2021 to 2023 (Fig. 5).

4.2. Impact of airport seasonality on airport passenger performance

The variability in definitions and measures of seasonality is acknowledged in aviation research. Halpern (2011), for example, employs Gini coefficients to quantify seasonal passenger demand at Spanish airports, finding variations depending on airport type and market served. Dobruszkes et al. (2022) contend that institutional, climatic, and geographic factors interact uniquely at each airport, emphasising the complexity of universally applicable definitions. Furthermore, Zuidberg (2017) identifies a non-linear relationship between seasonality and airport profitability, reinforcing the notion that simplistic or rigid definitions may not adequately reflect real-world situations.

The above studies collectively point to the pragmatic value of clearly articulated alternative criteria in enabling comparative analyses, despite their inherent limitations. Airport seasonality could only be calculated with respect to airports who provide monthly data to Airports Council International. Such airports account for ~90 % of passenger volumes but just 53.3 % of airport numbers. 2019 passenger numbers used to were used to determine seasonality. This study focuses on airports processing fewer than ten million passengers annually and reporting monthly data. This threshold was chosen to reduce distortion from the disproportionate influence of larger airports, which are both more likely to report monthly and manage significantly higher passenger volumes.

While there is no formally standardised threshold for categorising airport seasonality, this study adopts a 65 % seasonal concentration benchmark based on empirical traffic patterns observed in the *ACI* dataset (see below). This level represents a meaningful distinction between balanced and seasonally concentrated operations. As there is no agreed definition of seasonality, the authors developed two models – Scenario 1 and Scenario 2 (Fig. 6). If the ratio of passengers for the summer period as defined exceeds 65 % of the annual passenger total for 2019, it is classified as *summer seasonality*. If it is greater than 65 % for the winter period, then it is classified as *winter seasonality*. Otherwise,

European Airports
2023 Passenger Performance by Size Category

Airport Category	Per Annum Pax Range*	% Change FY 2023 vs FY 2022	% Change FY 2023 vs FY 2019
Largest Airports	Top Five	20.8%	-6.5%
Group 1	>25m	19.7%	-7.6%
Group 2	10-25m	18.3%	-10.2%
Group 3	5-10m	18.2%	4.3%
Group 4	1-5m	15.7%	2.0%
Group 5	0-1m	21.5%	-0.8%

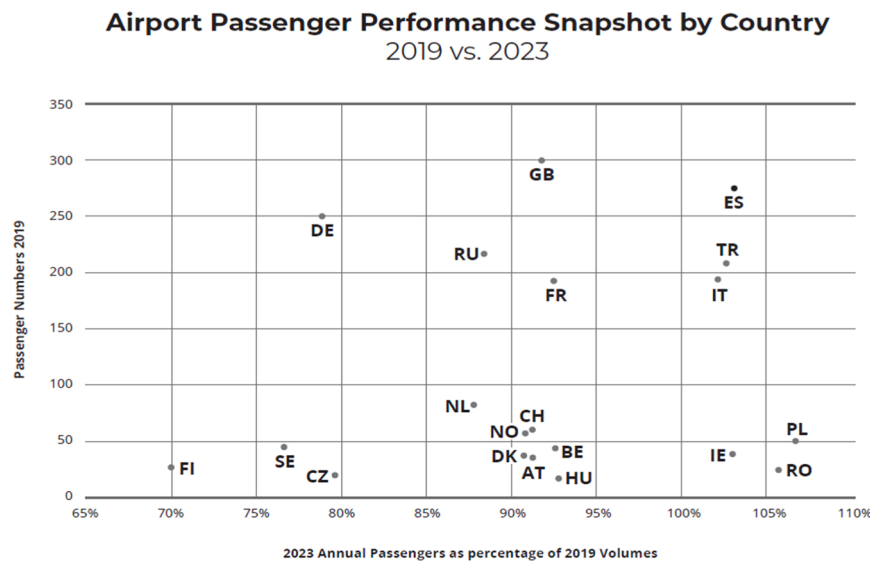**Fig. 2.** European Airports: 2023 Passenger Performance by Size Category.

Fig. 3. Airport Passenger Performance Snapshot by Country — 2019 versus 2023
[Source: Airports Council International Europe (February 2024) * Based on 2019 passenger numbers].
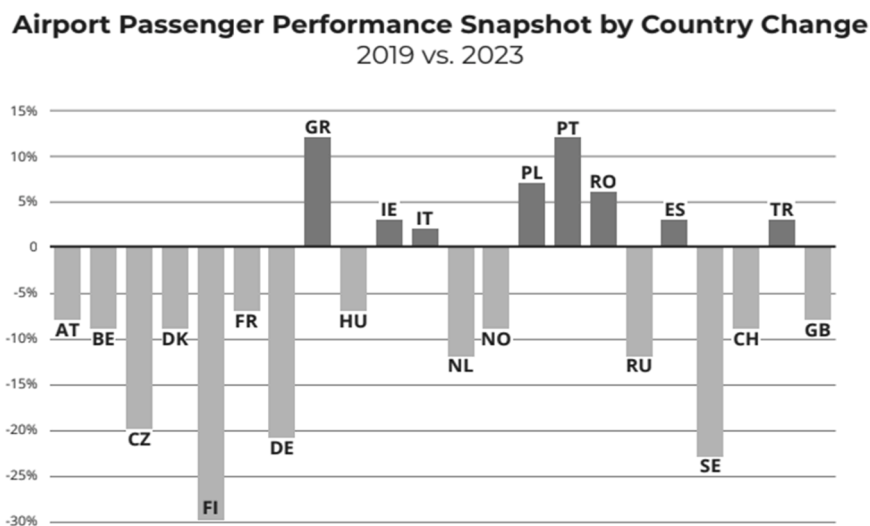[Source: *ACI* Intelligence Hub. Analysis by Authors].

Fig. 4. Airport Passenger Performance Snapshot by Country — 2019 versus 2023
[Source: ACI Intelligence Hub. Analysis by Authors].

the airport is 'non-seasonal'. A total of 448 European airports reporting monthly data and processing less than 10 m passengers per annum were considered.

Airport Seasonality Finding: In both scenarios considered, the majority of airports were not seasonal (370 in Scenario One and 418 in Scenario 2). More airports exhibit summer seasonal trends than winter ones. In Scenario One, 72 airports were summer seasonal and 6 winter seasonal, while in Scenario Two the numbers were 28 and 2 respectively. Airports processing fewer than ten million passengers annually, whether seasonal or not, showed similar recovery levels based on 2023 versus 2019 passenger numbers, although seasonal airports performed slightly more strongly. However, the modest difference indicates this trend is not conclusive.

Impact of Airport Location (Coastal versus Non-Coastal Profile) on Airport Passenger Performance

Coastal Airports Finding: There is no standard classification for what constitutes a 'coastal' airport, although Yesudian and Dawson (2021), in their assessment of the impact of a rise in sea levels on

airports, estimated that 1238 airports worldwide fell within the 'Low Elevation Coastal Zone'. In the absence of any agreed definition, the method of visual identification of airports within a certain distance of the coastline, is a reasonable substitute for exploring passenger recovery patterns, despite being an estimated measure rather than a precise definition. 113 airports were designated as 'coastal', being located approximately 15/20 km from a coastline (Flight Radar 24, 2023; author analysis). Airports at these locations saw a stronger recovery in 2023 relative to 2019 levels, likely driven by a return of tourism activity and 'pent-up' travel demand (Fig. 7).

[Sources: *ACI* Intelligence Hub; Flight Radar 24. Analysis by Authors]

Impact of Ownership Type on Airport Passenger Performance

Airport Ownership Finding: About two-thirds of airports were classified as fully or partially publicly owned (*ACI* Europe, 2016). Ownership type (public, private, or hybrid) generally did not impact passenger performance, except that fully public airports showed lower 2023 vs. 2019 performance (Fig. 8). Other factors like financial and
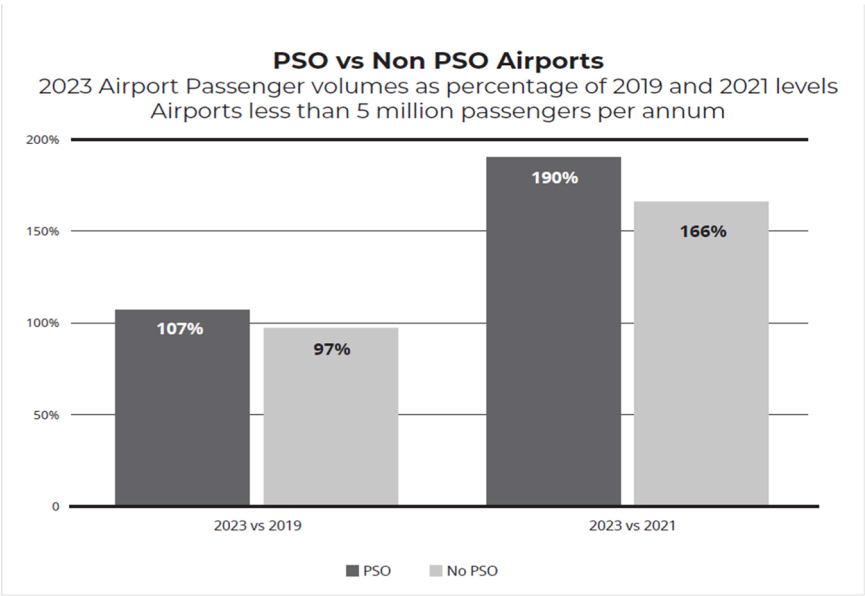
Fig. 5. Impact of PSO Routes
Impact of Public Service Obligation (PSO) Routes on Airport Passenger Performance (Airports Processing Less Than 5 Million Passengers per Annum)
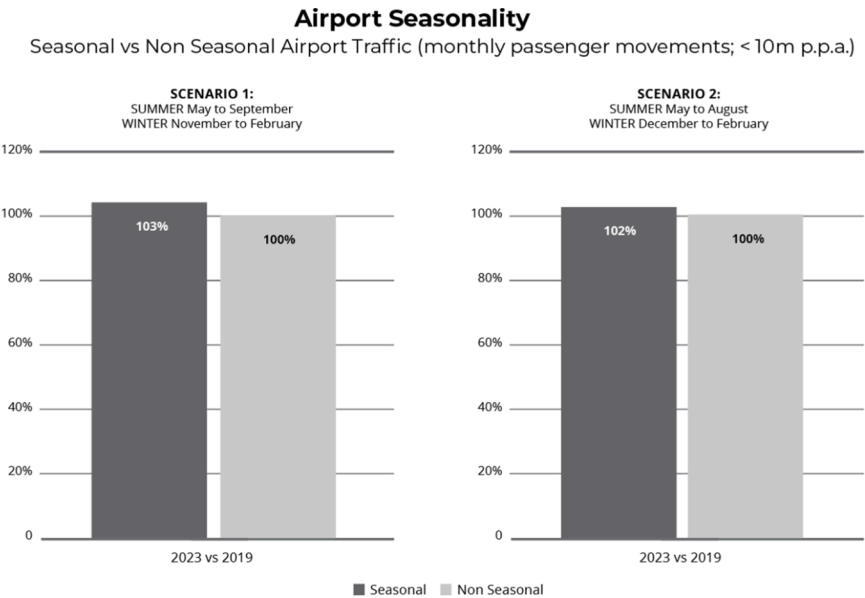[Source: ACI Intelligence Hub (2024); PSO Inventory: European Commission (2024)].

Fig. 6. Impact of Airport Seasonality. [Source: *ACI* Intelligence Hub. Assessment by Authors].

efficiency metrics, not covered in this paper, may explain this difference.

It should be noted that the external factors (e.g., PSO routes, airport ownership, and seasonality) assessed against the airport passenger data were deliberately selected based on their relevance to airport performance and the specific availability of reliable data. These factors were either explicitly obtainable from the *ACI* Intelligence Hub or clearly defined by external authoritative sources such as the European Commission (PSO route information) and Airports Council International (ownership types), ensuring the analysis was purposeful rather than arbitrary.

The findings above suggest on balance that airports with some of the variables assessed (PSO routes, coastal location) are likely to have a positive impact on passenger performance, showing stronger passenger performance and recovery in 2023 compared to 2019 base figures than levels experienced by airports without these features. This is likely due

to factors like the presence subsidised routes (PSO) and tourism activity (seasonal airports). The situation with respect to airport ownership is not as clear. However, when assessing seasonality and airport ownership impacts on passenger performance, it is not possible to be as conclusive. Further research is suggested to explore how the selected characteristics influence broader performance metrics and to assess how they might impact passenger recovery relative to airports without these traits.

4.3. Airport manager survey 2022: key results

Survey: During the summer of 2022, an online survey targeting airport managers was launched, featuring a comprehensive 25-question stakeholder questionnaire, including three open-ended questions for qualitative insights. The objective of this primary research component is to assess post pandemic changes in stakeholder activity and identify
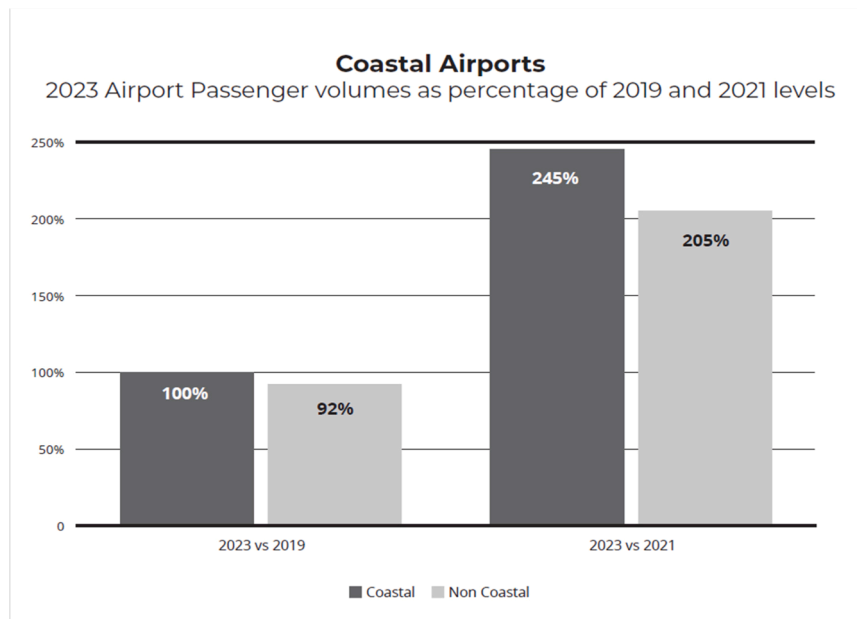
Table 1

Airport Manager View: Identification of Most Important Stakeholders (Scale 1–5) and Assessment of Most Significant Change in Airport Stakeholder Importance Since Pandemic Onset.

(a) Most Important Airport Stakeholders as assessed by respondents	Scale 1–5 (5 most important)	Ranking	(b) Most significant *increase* in stakeholder importance since onset of pandemic (% of respondents)	Ranking (increase in importance)
Passengers	4.5	1	30 %	6
Airlines	4.5	1	25 %	8
Aviation Regulators	4.3	3	32 %	4
Airport Employees	4.1	4	59 %	1
Airport Owners	4.0	5	48 %	2
National Government	4.0	5	48 %	2
Local Government	4.0	5	30 %	6
Concessionaires	3.8	8	31 %	5

[Source: Airport Manager Stakeholder Survey, 2023].

Table 2

Airports in Receipt of State Aid (2022).

Type of State Aid (2022)	% of Airports in Receipt of Aid (2022)
Air Route Subsidy	44 %
Air Route Promotion	42 %
Airport Improvement	50 %
COVID-19 Support	80 %
Support to Airline Partner	62 %
Other	23 %

[Source: Airport Manager Stakeholder Survey, 2022].

support, as well as the need to attract and retain staff amid recovery challenges. Airlines and passengers also grew in importance, although they were already rated highly.

During the period of the survey in 2022, most respondents (62 %) reported that remote/virtual communication was the most frequent engagement type, with 31 % reporting a mix of remote and face-to-face engagement activity. Only 7 % selected face-to-face as the most common style experienced at that time. 45 % of respondents felt that the nature of engagement was more structured, while 35 % believed it to be more ad-hoc. Only 20 % of managers responding felt that there was no change. Face-to-face stakeholder interactions might be expected to have increased since the survey period and return to more normal meeting conditions.

Most survey airports (62 %) had appointed a single airport manager to coordinate stakeholder activity, with other managers at these airports responsible for designated stakeholder relationships. Over 75 % of such activity was managed on a formal, structured basis (e.g. regular meetings, formal notes, follow-up actions). 82 % of those who answered the question reported that a regular review of stakeholder effectiveness (at least yearly) took place. Other research (Hiney et al., 2023) suggested that reviews of effectiveness were informal in nature, with the outcome influenced significantly by the assessment of personal and individual dynamics of specific stakeholder relationships.

Airport managers were surveyed on the nature, structure, and frequency of stakeholder engagement before and after the pandemic. The most common stakeholder meetings involved Airport Operator Groups (96 %), route conference attendees (61 %), and local communities (46 %). Since the pandemic, 57 % of managers reported increased engagement frequency, 30 % noted a decrease, and 13 % saw no change. Internal organisational stakeholders accounted for the joint highest level of stakeholder activity (67 % of airport managers), along with government and regulatory stakeholder engagement (same score), followed by other aviation stakeholders (e.g. airlines, ground handlers and concessionaires) at 65 %. Engagement with non-aviation stakeholders was more moderate (65 %), with only 19 % saying it had increased.

Respondents were asked about their experience with airport stakeholder groups, typically set up temporarily to promote airport and regional activity, often in response to market or structural changes that present new opportunities or threats (e.g., promoting growth or

preventing closure). Over half of the managers reported having experience with such groups.

The survey found that sustainability and decarbonisation activities were organised on a stakeholder basis, with an organisation-level sustainability stakeholder strategy, including Board/Director level oversight, in place in two thirds (67 %) of airports. Respondents stated that external collaboration was a feature of sustainability activity, including aviation organisations and sometimes other airports. Less than 10 % of airport managers stated that these activities are primarily internal, highlighting strong levels of external engagement and collaboration associated with this topic.

With respect to State aid, most respondent airports received such support during the pandemic (Table 2). While airport-specific State support (vertical aid) is normally reserved for airports with less than 3 m passengers per annum in Europe, all airports were eligible for COVID-19-related 'horizontal' aid provided to all industry sectors, covering (for example) wage subsidies and route support. The percentage of airports in receipt of or benefiting from such support was higher than it had been in the previous 10 years (2012). For example, Air Route Promotion (42 % versus 27 %); Airport Improvement (50 % versus 29 %) and Airline Support (62 % versus 32 %) all showed higher post-pandemic volumes.

Survey respondents identified key threats facing their airports, including geopolitical instability and fears of war, the potential resurgence of COVID-19 and related travel restrictions, and concerns over a prolonged recession affecting financial stability and forecasting. Additional threats included the industry's slow return to full operational health, challenges in funding capital investment, staffing shortages impacting operations, and increased competition, especially for smaller airports. Some managers also cited the weakened state of airlines, the rise of anti-flying sentiment, and climate initiatives as pressing concerns.

When identifying opportunities, respondents highlighted the resilience of the aviation industry, with stronger-than-expected demand and a rapid return of routes to pre-pandemic levels. Increased government support for critical connectivity, leaner operations, and enhanced flexibility through digitalisation were also noted. Some managers used the pandemic period to advance sustainability initiatives, while smaller airports saw potential opportunities arising out of larger airports' capacity issues, allowing them to attract more regional passengers.

From a stakeholder perspective, partnerships remained essential for communication and business resumption. One regional airport manager noted that while only 20 % of stakeholders are critical, the remaining 80 % consume most of their time. Another management challenge highlighted was the fact that while that local stakeholders often held strong opinions on management decisions, they possessed limited knowledge about airport operations.

5. Discussion

In light of industry and global events following the pandemic (from

2022), the topic of resilience became more central to discussions on how airports might navigate a rapidly evolving landscape of recovery, disruption and uncertainty. The experiences of airports during the COVID-19 pandemic highlighted the dual challenge of recovering passenger volumes while addressing broader operational and financial pressures. As the literature has shown, recovery strategies are shaped by complex stakeholder interactions, ever changing geopolitical conditions, and regulatory requirements. Effective resilience frameworks must therefore not only enhance an airport's recovery capabilities, but should also enable agility and adaptability to unknown future events. This paper contributes to these discussions by linking recovery trends, stakeholder engagement, and strategic frameworks into an integrated narrative on airport resilience. The analysis has used a combination of airport data and stakeholder insights to suggest an integrated approach to achieving resilience, underpinned by the development of the VUCAIR framework which is covered in Section 6.

Passenger recovery patterns following the COVID-19 crisis were notably uneven across European airports, influenced by a range of factors such as size, location, and the presence of low-cost carriers. Smaller airports, particularly those in tourism-dependent regions, demonstrated stronger passenger recovery, driven by pent-up travel demand to tourist locations and the resumption of Public Service Obligation (PSO) routes which benefit such airports to a greater extent than others. Nonetheless, the path to business recovery required that airports achieve more than just a resumption of passengers to 2019 (pre-pandemic) levels. Many airports focused on strict cost control measures to remain viable/competitive, also seeking revenue improvement and diversification. The airport manager survey showed that cost and operational measures, and stakeholder engagement activities, were prioritised in response to these challenges. Such findings point to the importance of linking airport recovery strategies to broader resilience initiatives, with airports that integrate an agile mindset into their planning frameworks likely to be better positioned to sustain business performance amidst ongoing uncertainty (a new normal). These observations are reflected in the proposal of the VUCAIR framework (next section), with its focus on adaptable responses to uncertainty, volatility and disruption.

Stakeholder collaboration emerged as a vital factor throughout the pandemic and subsequent recovery period. Effective stakeholder management was identified as a key enabler of maintaining operational continuity and its support in accelerating post-disruption recovery has been highlighted (Hiney et al., 2023). Airport managers highlighted the increased importance of airlines, employees, and government stakeholders in influencing strategic decision-making during and after the pandemic. In particular, the need for increased employee engagement rose in importance due to the impact of employee shortages and operational restructuring following a faster than expected 'return to the air' for many airports and airlines, especially during the summer of 2022. Government support also played a significant role in stabilising airport finances, with horizontal and vertical (industry focused) state aid crucial to airports' survival during this time. These dynamics align with existing literature on the need for coordinated approaches to crisis management, where effective stakeholder engagement enhances organisational flexibility. The VUCAIR framework supports these insights by positioning/accommodating stakeholder collaboration and adaptability as a strong component of airport resilience planning. By incorporating structured stakeholder coordination into such strategic frameworks, airports can better anticipate and respond to challenges arising out of interconnected pressures due to the effect of such uncertainty on operational and business performance.

6. VUCAIR: A framework response to a VUCA (Volatile, uncertain, complex and ambiguous) environment for airports

Events since 2020 have contributed to emergence of a post-pandemic VUCA environment for airports, as highlighted in Section 3.3. Increased uncertainty, an increasingly competitive airport market, and the unpredictable impact of external shocks have created a more volatile environment for airports. These factors expose potential vulnerabilities, highlighting the need for airports to develop greater strategic agility. Although effective planning and diversification can enhance strategic responsiveness and financial performance (De Wit, 2022), exceptional disruptions like the COVID-19 pandemic can exceed normal planning assumptions. Such disruptions, combined with ongoing geopolitical uncertainty, underscore the necessity for airports to adapt swiftly to exceptional 'shock' situations. In this evolving 'new normal,' change remains constant, forecasting less dependable, and regulatory shifts more frequent (Robinson, 2020). Furthermore, the rising risk of rare and unpredictable 'Black Swan' events demands continued vigilance, as emerging insights may render past responses ineffective (De Wit, 2022; Liu, 2023). Year on year passenger movements became more volatile during and after the pandemic (Fig. 9).

Indeed, the US Transportation Research Board developed a comprehensive airport guide and methodology to help airport practitioners and stakeholders manage unexpected events as part of their planning and forecasting processes (ACRP, 2023). This toolkit included suggestions for analysing, forecasting, and responding to the impact of a variety of shock events on various airport types:

- The short and long-term effects of shock events on airline fleet composition, with implications for airport layout, planning, finances, and concessionaires.
- Identifying and capitalising on airport opportunities that may arise during shock events.
- Integrating these considerations into airport forecasting policies and procedures.
- Building a more resilient airport business model.

The analysis of the impact of pandemic and post-pandemic events such as greater geopolitical fragility, as described in previous sections, highlighted major challenges for airports and their stakeholders. Volatility in passenger demand, uncertainty in global travel regulations, complexity in integrating advanced technologies, and ambiguity in future market trends have had a significant impact on the operation of airports. These factors have given rise to a challenging environment for the sector and the need for strategic preparedness. Semi-structured interviews and findings from the airport manager stakeholder survey also pointed to a more uncertain future environment following the pandemic and related events since 2020.

VUCAIR: An Airport Framework for VUCA Assessment and Action

Drawing on the preceding analysis, the VUCAIR framework, a new practical tool to help airports respond effectively to volatile, uncertain, complex, and ambiguous (VUCA) conditions, is proposed. This framework integrates key research insights, combining stakeholder perspectives with theoretical resilience concepts to support the achievement of operational and business resilience in airports.

The VUCAIR framework uses VUCA's four interrelated factors as the basis for a structured, strategic assessment. Designed as both an assessment and action-oriented tool, VUCAIR provides airport practitioners and policymakers with a clear template to systematically assess and proactively respond to challenges, a particularly important feature
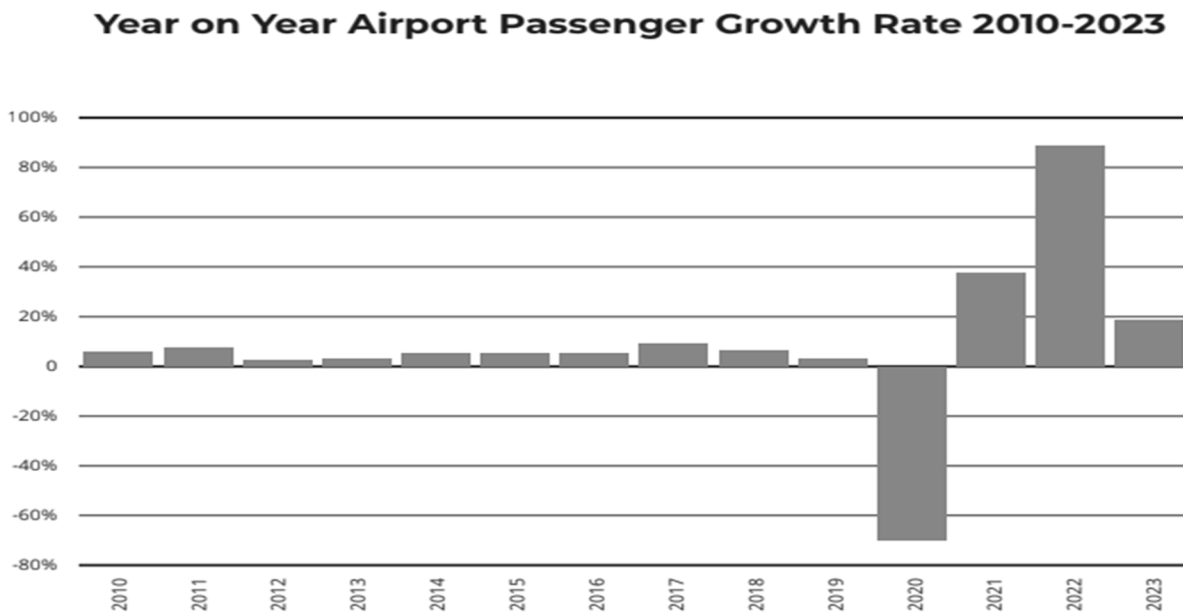
Year on Year Airport Passenger Growth Rate 2010-2023

Fig. 9. Year on Year Airport Passenger Movements (%). [Source: *ACI* Intelligence Hub. Analysis by Authors].

in the post-pandemic context.

By bridging descriptive research outcomes with practical applications for airports, this framework facilitates informed decision-making, strategic planning, and effective operational responses, thereby increasing management focus and adaptability and enhancing airport resilience in an increasingly uncertain environment. In conclusion, the VUCAIR framework addresses a key long-term research insight: the operational landscape for regional airports is expected to mirror the volatility of the post-pandemic period rather than the relative predictability of the pre-pandemic era.

VUCAIR Components and Their Relationship to Research Findings

The VUCAIR tables below (Tables 3 and 4) offer practical examples of how airports can adopt and utilise the VUCAIR Framework. Each table corresponds directly to the four identified VUCA components, linking assessment findings (from research) to suggested strategic airport actions. These examples, alongside the subsequent VUCAIR Template for Airport Planning Actions (Table 4), highlight assessments and actions for airports operating under increasingly uncertain conditions. Key considerations include airport planning, operational and digital enhancements, stakeholder collaboration and sustainability initiatives, detailed further in Table 4.

VUCAIR *Assessment* components identified through research (summarised in Table 3) include:

- Volatility: Unexpected, unstable events with uncertain durations, though generally understandable.
- Examples: Geopolitical events, greater unpredictability of airline commitments and passenger demand, increasing cost structures, sudden disruptive events.
- Uncertainty: Events with unclear future trajectories, although management understand basic cause-and-effect relationships.
- Examples: The uncertain 'new normal', unpredictable stakeholder behaviour, pandemic-type recurrence, economic shocks, recurring

crisis impacts, financial instability - all affecting the ability of airports to respond effectively to such events
- Complexity: Situations involving numerous interconnected parts / variables, and information that may overwhelm airport decision-making processes.
- Examples: Multifaceted stakeholder relationships, varying operational and financial considerations, balancing passenger growth and sustainability, difficulties in assessing the relationships between these variables in real time.
- Ambiguity: Events with unclear causal relationships, involving unprecedented or rapidly evolving scenarios.
- Examples: Imperfect stakeholder information, rapidly changing health and security guidelines, uncertain macroeconomic impacts, unpredictable 'Black Swan' events (e.g., Boeing 737 MAX grounding). Traditional planning frameworks do not often provide for a planned response to such events.

VUCAIR *Action* Components include the following airport actions:

- Increased strategic agility and flexibility in infrastructure and resource deployment to manage volatility.
- Enhanced contingency planning and strengthened risk and financial frameworks to mitigate uncertainties and improve resilience.
- Strong stakeholder collaboration frameworks and effective communication strategies to address complexity.
- Training and development programmes focused on developing skills to effectively manage ambiguous situations.

This strategic approach, as expanded below, seeks to strengthen airport resilience and responsiveness in the uncertain operational landscape described above. Table 3 provides a framework for airports to inform each VUCA element, explore the potential consequences of it for airports and identify potential response actions.

Table 3
VUCAIR, an Airport Framework for VUCA Assessment and Action. Part One.

VUCA Component	Volatility	Uncertainty	Complexity	Ambiguity
Component Characteristics*	"The challenge is unexpected or unstable and may be of unknown duration, but it's not necessarily hard to understand; knowledge about it is often available."	"Despite a lack of other information, the event's basic *cause and effect* are known. Change is possible, but not a given."	"The situation has many interconnected parts and variables. Some information is available or can be predicted, but the volume or nature of it can be overwhelming to process."	"Causal relationships are completely unclear. No precedents exist; you face 'unknown unknowns'"
Examples of this VUCA Component	• Current economic and geopolitical elements evolving more intensely. • Airlines are increasingly less committed. • Key cost lines, shifting more quickly • Effect of pandemic on airport activity mix • Effect of war on air travel Immediate airport impact of specific events, e.g. restrictions	• Lower predictability / certainty regarding • More demanding airlines and passengers). • Aircraft supply chains not as reliable, affecting supply • Unknown impact of adverse events on traffic dynamics • Impact of increasing level of natural weather events • Management of uncertainty and dealing with uncertain recovery periods • Airline and Airport behaviours not as rational • Disruptors appearing all along the value chain. • Competitor 'new business' pricing - problematic in terms of airport ability to respond. • Regulatory environment • 'Black Swan' event	• Aviation is a complex and interconnected industry dealing with enormous volumes of activity • An airport's role in requires multi-faceted stakeholder relationships covering a broad range of activity and functions. • Complexity arises because of the need to process and integrate systems • An airport's need to balance activity with sustainability and green energy activity, in a cost-efficient manner	• Unclear link between macro trends and airport-by-airport economics. • Need to manage activities and make decisions in ambiguous environments, • Imperfect information. • Rapidly evolving health, safety and security guidelines • Airport stakeholder uncertainty is a feature of such an environment • This observation applies primarily to commercial and relationship activities, as regulated day-to-day operations activity must be clear and complied with.
Actions and/or positioning in Response to Challenges [Indicative]	• Responsive strategic mindset. • Flexible resource components for allocation • Agile infrastructure • Talent — effective resourcing policies and right people in key roles • Increased organisational defences — e.g. cash reserves, selective cost discipline. • Right balance with respect to resource planning to meet future shocks	• Planning processes should reflect likely future non-linear trends. • Understand uncertainty and convey agility • Assess how impact of uncertainty is likely to affect passenger / cargo demand, and response to same. • Scenario and contingency planning. • Risk management activities and • Actions to build financial resilience, • Develop and share key information with main stakeholders. • Airport anticipation of uncertainty and response to same • Plan response to key (step) changes triggered by likely trigger points. Long term/master planning remains a key element, but a necessarily more flexible and responsive	• Purposeful, solution-focused mindset, • A well-developed airport stakeholder management framework • Designed to deliver effective collaboration amongst key groups in time of crisis — • Appropriate level of specialist skills. • Focus resources on anticipating and addressing specific complexities • Financial benefit through flexible use of airport facilities	• Assess and seek to comprehend/ respond to the situation as fully as possible, • Identify/execute appropriate actions. • Effective communication of levels of certainty/uncertainty key: what is known, and what is not known. • Flexibility with stakeholders vital • Identify and test contingency scenarios.

[*Characteristics Source: What VUCA Really Means for You (Bennete and Lemoine, 2014) Adapted by Authors].

VUCAIR Airport Planning Template

Having assessed the challenges facing the airport using the VUCA Framework above, the next step for an airport is to plan and execute its response to these factors. Table 3 highlights action areas for consideration in light of an airport's assessment of the above factors and their potential impact. Suggested strategic responses based on the above assessment are detailed in the VUCAIR planning template below (Table 4). This VUCAIR component highlights typical specific action areas which an airport might consider to (a) effectively react to airport threats and (b) identify the opportunities presented by VUCA challenges for innovation, operational efficiency, digitalisation, sustainability (Table 4; Column 3). These actions will contribute to building an effective airport 'defence' in a VUCA environment, and will enable delivery of improved performance and airport positioning, from a people, financial, operating and stakeholder standpoint.

7. Conclusions

The analysis of aviation market conditions and key factors affecting airport performance—based on passenger data, survey results, and research observations—reveals that the industry's recovery from the pandemic was faster and stronger than expected, with larger airports rebounding first but smaller ones quickly returning to 2019 levels. A niche category, experiential travel, has grown since the pandemic, with more travellers attending events abroad. Sustained resilience was identified through the continued recovery and growth of aviation through 2022 and 2023.

Pandemic-related impacts remained a core challenge. Survey respondents cited geopolitical conflicts, constrained aircraft supply, and the ongoing effects of airport congestion and activity capping in 2022 as sources of sector uncertainty. The unexpectedly rapid return of demand, staffing shortages, and supply chain issues in aircraft production contributed to a more fragile operating environment, affecting

Table 4

VUCAIR Template for Airport Planning Actions in Response to the VUCA Assessment Conducted Using the Above Framework. Part Two.

1. (Actions necessary to respond effectively to 'VUCA' Environment)	2. Description of Airport Response Areas to Consider	3. <Airport to insert specific actions in this column; examples provided>
Short- and Long-Term Horizon Planning (Flexibility, Agility)	Flexible strategies that can be adjusted speedily in response to changing circumstances Continued awareness of relevant airport Key Performance Indicators (KPIs) and subtle changes in the same Scenario planning, supporting informed decision-making	More frequent airport strategy reviews than before Identify any change in key airport metrics, e.g. cost ratios and aeronautical versus non-aeronautical revenue mix Propose airport actions in response to such changing trends
Inclusive and Co-Ordinated Stakeholder Collaboration	Build and maintain strong relationships with key airport stakeholders, in particular airlines, government bodies, suppliers, and local communities Enhanced and effective problem-solving during times of rapid change and disruption 'Make friends before you need them'!	Identify which airport stakeholders have the greatest current influence on airport activity, e.g. airlines, employees, government Develop engagement strategies to maximise airport positioning, e.g. new routes, staff retention, policy advocacy
Technology and Digital Evolution Leadership	Awareness of key airport impacts associated with key IT trends, hardware and software Data analytics, artificial intelligence, cybersecurity and robotics Enable secure and streamlined airport operations, with optimum allocation of (scarce) resources Enhanced employee and passenger experiences	Review of all airport processes from a digitalisation perspective Objectives: better customer and staff experience, reduced costs, increased airport efficiency, contactless travel
Continuous, Agile and Adaptive Learning	Best in class industry training and continuous learning programmes Adaptive mindset and updated awareness of best practices, regulations and guidelines, on top of current aviation trends Ensure a more speedy and agile airport response to changing industry circumstances	Increased management focus on key future aviation/airport trends Identification of airport specific impacts Smartened airport infrastructure, e.g. ability to change use of terminal space, for example mobile concession structures
Effective Communication and Engagement	Regular, consistent and transparent communication with all stakeholders Clear communication as appropriate to airport stakeholders affected by operational, business and/or safety/regulatory change Comfort and reassurance mindset, assertive where necessary	Development of key airport messages which articulate key focus, e.g. local businesses use local airport; government department supportive policy; passengers and community sustainability focus
Contingency Planning and Building Financial Resilience	Need for suite of all-embracing contingency/resilience plans Appropriate financial reserves to weather unforeseen events These should outline protocols for rapid response and recovery To be used when managing airport effects of further health crises, natural disasters, geopolitical upheavals and once off incidents	Review existing risk frameworks to account for greater future threats, e.g. cybersecurity and AI Develop airport pandemic / shock-event contingency plans Financial resilience measures, achieving balance between costs, increased revenue and a reserves policy
Adapting to Climate Change and Delivering Sustainability / 'Green' Initiatives	Focus on transition to renewable and more efficient energy solutions related to core airport activity and operations Plan for effective response/adaptation to sustained change in weather and climate patterns Develop and build sustainable airport infrastructure Green energy options for key customers, especially airlines but also concessionaires	Sustainability a core activity and reflected in airport strategy and performance frameworks Essential baseline factors achieved; all new investments in infrastructure to improve environmental footprint and reduce airport CO_2 emissions Future trends, e.g. Sustainable Aviation Fuels — leader or follower?

[Source: Developed by Authors].

operations, service levels, and customer experience. Attracting and retaining staff remained challenging, as cost and efficiency measures made other sectors, like retail, more appealing in terms of wages, contract conditions, and work hours. Disruptions from extreme weather, IT outages, and airspace closures further stressed operations. Additionally, environmental and sustainability initiatives became more integrated into airport strategies, influencing daily operations both airside and landside.

Research findings from literature and reportage, analysis of recovery trends and stakeholder survey findings collectively informed the development of the VUCAIR framework. The increasingly volatile and competitive environment airports face means that traditional planning cycles are likely to be disrupted by unexpected events more frequently and within shorter periods. The VUCAIR framework proposed offers a structured approach to managing such conditions by integrating theoretical perspectives (VUCA) and practical learnings from recent airport experiences. VUCAIR can highlight key response/action areas for airports, including scenario planning, stakeholder management, and innovation. These factors can become mechanisms to enhance airport agility and operational stability. By drawing upon and holistically considering research findings from earlier sections, the VUCAIR model provides airports with actionable strategies to strengthen their resilience, positioning them to better manage the ongoing complexities of a much more uncertain post-pandemic era.

This research provides valuable insights by demonstrating how external shocks and crises can test the resilience of airports, showing how airports navigated a broad range of challenges during an uncertain period in 2022–2023. Their response to the COVID-19 pandemic and other previous 'shock' events, has highlighted the ability of airports to manage and deal with unexpected adversity in a resilient manner, continuing and enhancing their key connectivity role in an increasingly fragile and uncertain world. Based on these findings, resilience is likely to be essential for aviation organisations, with a balanced approach that emphasises operational and financial stability, customer engagement, and sustainability improvements, all within an evolving regulatory landscape. Future research could expand beyond passenger-only

performance data by incorporating additional metrics, especially benchmarking data, for a more comprehensive understanding of post-pandemic recovery. Further research might also support the drive towards a more standardised and validated definition of airport characteristics, including those highlighted in this paper. Until then, while recognising the current constraints, clearly stated substitute criteria can enable comparative performance analyses such as those presented above,

This paper advances the literature on airport resilience during challenging times by identifying critical strategies for adapting to and mitigating the effects of a volatile and uncertain external environment. It provides practical insights for airport stakeholders and proposes an actionable framework to enhance operational continuity and strategic recovery. The paper's research findings suggest that volatility and uncertainty are the dominant VUCA challenges currently impacting airport operations, particularly in the post-pandemic period. Furthermore, a key long-term impact which emerged during the course of this research, was that the future landscape for airports was more likely to be analogous to the post-pandemic volatile period rather than the comparatively more stable and predictable pre-pandemic period. These factors suggest that airports require a robust planning approach to systematically assess, anticipate, and respond to increasingly prevalent operational challenges.

The paper contributes methodologically and theoretically through the development of a strategic framework prototype, VUCAIR, to support airport management in volatile and uncertain times. Development of VUCAIR fills an existing research gap by offering a practical, airport-specific tool to navigate disruptions such as geopolitical instability and economic shocks, proposing an original approach to managing these circumstances through a customised framework that helps airport management enhance resilience and operational effectiveness. The VUCAIR framework enables airports to be better prepared to meet the challenges of economic volatility, geopolitical instability and other unforeseen crises, while improving their agility and adaptability during rapidly changing and increasingly uncertain times in a manner that benefits both airports and industry stakeholders. This framework aims to prepare airport leaders to manage the increasingly frequent VUCA factors that are likely to persist in the airport, aviation, and broader economic environments.

CRediT authorship contribution statement

Noel Hiney: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Marina Efthymiou:** Writing – review & editing, Writing – original draft, Conceptualization. **Edgar Morgenroth:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Noel Hiney reports financial support was provided by The Shannon Airport Group. Marina Efthymiou sits on the editorial board of the ATRS Journal If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

ACI Europe. (2016). The ownership of European airports. Available at: https://www.aeroport.fr/uploads/documents/ACI %20EUROPE %20Report_The %20Ownership %20of %20Europes %20Airports %202016.pdf [Accessed 25 September 2023].

ACI Europe. (2023a). ACI Traffic Report, Q4, H2 and full year, 2022. Available at: Https://member.aci-europe.org/component/downloads/downloads/6798.html [Accessed 5 September 2023].

ACI Europe. (2023b). European Regional Airports. *Sustainably connecting people, places and products.* Available at: Https://www.aci-europe.org/downloads/publications/EUROPEAN %20REGIONAL %20AIRPORTS %202023.pdf [Accessed 20 October 2023].

ACRP. (2023). Incorporating shock events into aviation demand forecasting and airport planning. *National Academies of Sciences, Engineering, and Medicine.* Available at: Https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5026 [Accessed 24 January 2024].

Airports Council International. (2024). The Intelligence Hub: Take advantage of actionable airport performance intelligence, all in one place. Available at https://aci.aero/programs-and-services/intelligence-hub/[Accessed 25 November 2024].

Akkaya, B., & Sever, E. (2022). Agile leadership and organization performance in the perspective of VUCA. *post-pandemic talent management models in knowledge organizations* (pp. 213–228). IGI Global.

Amankwah-Amoah, J., Khan, Z., & Osabutey, E. L. (2021). COVID-19 and business renewal: Lessons and insights from the global airline industry. *International Business Review, 30*(3), Article 101802.

Arora, M., Tuchen, S., Nazemi, M., & Blessing, L. (2021). Airport pandemic response: An assessment of impacts and strategies after one year with COVID-19. *Transportation Research Interdisciplinary Perspectives,* (11), Article 100449.

Basimakopoulou, M., Theologou, K., & Tzavaras, P. (2022). Civil Aviation Approach to safety risk management: A new perspective on a mature process. *International Journal of Applied Research in Management and Economics, 5*(4), 14–28.

Bennett, N., & Lemoine, J. (2014). What VUCA really means for you. *Harvard business review, 92*(1/2).

Bloch, J. H., Janko, K., Thessen, T., Jensen, O. B., & Lassen, C. (2021). Not all hubs are made equal: A case study of airport governance in Europe. *European Urban and Regional Studies, 28*(3), 241–262.

Bolton, B. (2020). Effective project leadership and culture under stay-home orders. *Journal of Airport Management, 15*(1), 28–39.

Budd, L., Ison, S., & Adrienne, N. (2020). European airline response to the COVID-19 pandemic–Contraction, consolidation and future considerations for airline business and management. *Research in Transportation Business & Management, 37,* Article 100578.

Colak, O., Enoch, M., & Morton, C. (2023). Airport business models and the COVID-19 pandemic: An exploration of the UK case study. *Journal of Air Transport Management, 108,* Article 102337.

de Wit, J. (2022). Black swans or grey rhinos on the runway? The role of uncertainty in airport strategic planning. *The Sir Transportation Industry* (pp. 225–245). Elsevier.

Deasy, G. (2021). European Union and United Kingdom competition law developments in the aviation sector: January to June 2021. *Air and Space Law, 46*(4/5).

Dima, G., Meseşan Schmitz, L., & Şimon, M. C. (2021). Job stress and burnout among social workers in the VUCA world of COVID-19 pandemic. *Sustainability, 13*(13), 7109.

Dobruszkes, F., Decroly, J. M., & Suau-Sanchez, P. (2022). The monthly rhythms of aviation: A global analysis of passenger air service seasonality. *Transportation Research Interdisciplinary Perspectives, 14,* Article 100582.

Douglas, S. (2022). Fostering women's resilience in the aviation sector. In *Women, work and transport, 16* pp. 207–225). Emerald Publishing Limited.

Eccles, M., & Hernandez-Morales, A. (2020). Europe's regional airports go into a coronavirus-induced nosedive. *Politico.* Available at: Https://www.politico.eu/article/europe-regional-airports-go-into-a-pandemic-induced-nosedive/ [Accessed 23 October 2023].

Efthymiou, M., & Papatheodorou, A. (2019). EU Emissions trading scheme in aviation: Policy analysis and suggestions. *Journal of Cleaner Production, 237,* Article 117734.

EUROCONTROL. (2022). Aviation intelligence unit think paper #1, 1 January. Available at: Https://www.eurocontrol.int/sites/default/files/2022-01/eurocontrol-think-paper-15-2021-review-2022-outlook_0.pdf [Accessed 7 October 2022].

European Commission. (2020). Communication from the commission temporary framework for state aid measures to support the economy in the current COVID-19 outbreak 2020/C 91 I/01. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ %3AJOC_2020_091_I_0001 [Accessed 14 September 2023].

European Commission. (2023). State aid: Commission prolongs the possibility to grant operating aid to certain regional airports. Available at: Https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3710 [Accessed 23 September 2023].

European Commission. (2024). PSO inventory table - situation on 17/02/2023 Available at: Https://transport.ec.europa.eu/document/download/9168af3e-67c7-430f-b46c-61b76236d8cb_en?filename=pso_inventory_table_2023-02.pdf [Accessed 24 January 2024].

Flight Radar 24. (2023). All airports filter. Available at: Https://www.flightradar24.com/53.41,-7.19/9 (Subscription). [Accessed 23rd October 2023].

Florido-Benítez, L. (2023). The role of the top 50 US cargo airports and 25 air cargo airlines in the logistics of e-commerce companies. *Logistics, 7*(1), 8.

Georgiadis, P. (2023). European airport boss calls for scrutiny of rising airfares. *Financial Times.* Available at: Https://www.ft.com/content/d311bea0-67ff-487f-aa63-48a05ffb6175 [Accessed 24 October 2024].

Graham, A., Warnock-Smith, D., O'Connell, J. F., Efthymiou, M., & Zheng, X. (2023). Market Developments on Chinese International Air Passnger Markets in Light of COVID-19 Policy Measures. *Sustainnability, 15*(2), 1525.

Greer, F., Rakas, J., & Horvath, A. (2020). Airports and environmental sustainability: A comprehensive review. *Environmental Research Letters, 15*(10), Article 103007.

Grimme, W., Maertens, S., & Schröpfer, A. (2018). Options for traffic growth at smaller European airports under the European commission's guidelines on state aid. *Transportation research procedia, 35,* 130–139.

Guo, J., Li, Y., Yang, Z., & Zhu, X. (2021a). Quantitative method for resilience assessment framework of airport network during COVID-19. *PLoS One, 16*(12), Article e0260940.

Guo, J., Zhu, X., Liu, C., & Ge, S. (2021b). Resilience modeling method of airport network affected by global public health events. *Mathematical Problems in Engineering, 2021* (1), Article 6622031.

Guo, J., Yang, Z., Zhong, Q., Sun, X., & Wang, Y. (2023). A novel resilience analysis methodology for airport networks system from the perspective of different epidemic prevention and control policy responses. *PLoS One, 18*(2), Article e0281950.

Halpern, N. (2011). Measuring seasonal demand for Spanish airports: Implications for counter-seasonal strategies. *Research in Transportation Business & Management, 1*(1), 47–54.

Helmold, M., Küçük Yılmaz, A., Flouris, T., Winner, T., Cvetkoska, V., & Dathe, T. (2022). Lean Management in Aviation. *Lean management, kaizen, kata and keiretsu: Best-practice examples and industry insights from japanese concepts* (pp. 129–182). Cham: Springer International Publishing.

Hiney, N., Efthymiou, M., & Morgenroth, E. (2023). Impact of COVID-19 on Irish airport stakeholder relationships. *Annals of Tourism Research, 102*, Article 103622.

Hiney, N., Efthymiou, M., & Morgenroth, E. (2024). European Regional Airports: Emerging from the Storm or Facing a Gathering Storm? In C. McNally, P. Carroll, B. Martinez-Pastor, B. Ghosh, M. Efthymiou, & N. Valantasis-Kanellos (Eds.), *Transport Transitions: Advancing Sustainable and Inclusive Mobility. TRA conference 2024. Lecture Notes in Mobility*. Cham: Springer. https://doi.org/10.1007/978-3-03-85578-8_90.

Huang, C. N., Liou, J. J., Lo, H. W., & Chang, F. J. (2021). Building an assessment model for measuring airport resilience. *Journal of Air Transport Management, 95*, Article 102101.

Janić, M. (2022). Analysis and modelling of airport resilience, robustness, and vulnerability: Impact of COVID-19 pandemic disease. *The Aeronautical Journal, 126* (1305), 1924–1953.

Jensen, L. L., Bonnefoy, P. A., Hileman, J. I., & Fitzgerald, J. T. (2023). The carbon dioxide challenge facing US aviation and paths to achieve net zero emissions by 2050. *Progress in Aerospace Sciences, 141*, Article 100921.

Kim, E., Beckman, S., Kim, K.H. and Santema, S. (2022). Designing for dynamic stability in an uncertain world: A media content study of the aviation industry.

Kivits, R., & Sawang, S. (2021). Adelaide Airport. *The Dynamism of Stakeholder Engagement: A Case Study of the Aviation Industry*, 55–75.

Lemonnier, V. (2021). Concentrations in the aviation sector: How to maintain the level playing field for airlines and airports? *ZEuS Zeitschrift für Europarechtliche Studien, 24* (3), 485–511.

Lennon, J. (2022). How can airports go from bricks to clicks by accelerating digital retailing strategies? *Journal of Airport Management, 16*(3), 233–243.

Liu, X. (2023). The Economic Environment and Black Swan Events: Taking COVID-19 as an example. *Journal of Education, Humanities and Social Sciences,, 23*, 336–341.

Lubowiecki-Vikuk, A., & Sousa, B. (2021). Tourism business in a vuca world: Marketing and management implications. *Journal of Environmental Management & Tourism, 12* (4), 867–876.

Major, J., & Clarke, D. (2021). Regenerative tourism in Aotearoa New Zealand–A new paradigm for the VUCA world. *Journal of Tourism Futures, 8*(2), 194–199.

Mayer, C. H., & Wilke, K. (2022). Leading through VUCA times for a sustainable future of work: Expert views on the global automotive industry. *Leadership after COVID-19: Working together toward a sustainable future* (pp. 253–268). Cham: Springer International Publishing.

Müller, A., Walls, J. L., & Wittmer, A. (2022). Sustainable aviation: An introduction. *Sustainable aviation: A management perspective* (pp. 1–22). Cham: Springer International Publishing.

Nawas, R. (2023). Discover the 5 trends shaping the next generation of airports. *Oliver Wyman*. Available at: Https://www.oliverwymanforum.com/mobility/2023/jul/di scover-the-5-trends-shaping-the-next-generation-of-airports.html [Accessed 23 September 2023].

Posaner, J., & Nostlinger, N. (2020). How to recycle an airport. *Politico*. Available at: Https://www.politico.eu/article/how-to-recycle-an-airport-berlin-brandenburg/ [Accessed 24 October 2023].

Ramakrishnan, D. (2021). Leading in a VUCA World. *Ushus Journal of Business Management, 20*(1).

Rangaswamy, E., Hoe, W.H.K. and Nawaz, N. (2022). Impact of COVID-19 pandemic on Singapore's aviation industry.

Robinson, J. (2020). Thoughts on the post-pandemic new normal in air travel. *Journal of Airport Management, 15*(1), 6–19.

Romig, T. (2021). A collaborative approach to business continuity and organisational resilience when dealing with a major crisis, such as COVID-19. *Journal of Airport Management, 15*(3), 226–234.

Serrano, F., & Kazda, A. (2020). The future of airports post COVID-19. *Journal of Air Transport Management, 89*, Article 101900.

Sinha, D., & Sinha, S. (2020). Managing in a VUCA world: Possibilities and pitfalls. *Journal of Technology Management for Growing Economies, 11*(1), 17–21.

Sobieralski, J. B., & Hubbard, S. M. (2023). Turbulent skies ahead? Pandemic related workforce issues in air transportation. *Transport Policy, 130*, 84–88.

Suau-Sanchez, P., Voltes-Dorta, A., & Cugueró-Escofet, N. (2020). An early assessment of the impact of COVID-19 on air transport: Just another crisis or the end of aviation as we know it? *Journal of Transport Geography, 86*, Article 102749.

Sun X., Wandelt S., Zhang A. (2022) Aviation under COVID-19 pandemic: Status quo and how to proceed further?. Available at SSRN 4031476. 2022 Feb 10.

Sun, F., Yin, H., Sun, X., Wang, X., & Zhang, Y. (2024a). Resilience analysis of cities' air accessibility under disruptions. *Journal of Air Transport Management, 120*, Article 102671.

Sun, X., Zheng, C., & Zhang, A. (2024b). COVID-19 and aviation, lessons learned from the trenches: A survey among participants at the 26th ATRS World Conference. *Journal of the Air Transport Research Society, 2*, Article 100005.

Tang, H., Yu, J., Lin, B., Geng, Y., Wang, Z., Chen, X., Yang, L., Lin, T., & Xiao, F. (2023). Airport terminal passenger forecast under the impact of COVID-19 outbreaks: A case study from China. *Journal of Building Engineering, 65*, Article 105740.

Tuchen, S., Arora, M., & Blessing, L. (2020). Airport user experience unpacked: Conceptualizing its potential in the face of COVID-19. *Journal of Air Transport Management, 89*, 101919.

Wandelt, S., Zhang, A., & Sun, X. (2025). Global Airport Resilience Index: Towards a comprehensive understanding of air transportation resilience. *Transportation Research Part D: Transport and Environment, 138*, Article 104522.

Wang, X., Chen, Z., & Li, K. (2022). Quantifying the resilience performance of airport flight operation to severe weather. *Aerospace, 9*(7), 344.

Worley, C. G., & Jules, C. (2020). COVID-19's uncomfortable revelations about agile and sustainable organizations in a VUCA world. *The Journal of Applied Behavioral Science, 56*(3), 279–283.

Yesudian, A. N., & Dawson, R. J. (2021). Global analysis of sea level rise risk to airports. *Climate Risk Management, 31*, Article 100266.

Zuidberg, J. (2017). Exploring the determinants for airport profitability: Traffic characteristics, low-cost carriers, seasonality and cost efficiency. *Transportation Research Part A: Policy and Practice, 101*, 61–72.