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PROCEEDINGS OF THE FOURTH INTERNATIONAL AVIATION MANAGEMENT CONFERENCE, IAMC – 2022, DUBAI, UAE, 21 – 22 NOVEMBER 2022

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Editors

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Emirates Aviation University

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Message from the Conference Chairman

We are very pleased to host the fourth International Aviation Management Conference (IAMC) at Emirates Aviation University (EAU) in Dubai, United Arab Emirates, from the 21st to the 22nd of November 2022 under the theme of ***The Future of Aviation: COVID-19 Pandemic and Challenges***. The IAMC has now become a recurring conference following the success of the previous events, as well the positive feedback received from keynote speakers, sponsors, authors, and other participants.

The goal of the conference is to bring together aviation management researchers, professionals, professors, and students to share their ideas and knowledge of case studies and best practices. This year's conference covers several topics which include, airline operation and management, air transport policy and regulation, airport planning and management, aviation management and strategy, aviation finance and economics, aviation law, aviation safety and security, sustainable aviation, technical advances and impact, and women in aviation.

The invitation for papers has attracted authors from several countries around the world. The Technical Committee carried out a blind review and accepted twenty-seven papers for oral presentation. We apologize to those who have missed the deadlines, and anticipate that more authors, from both the academia and the industry, will be encouraged to prepare their work for publication in the next IAMC. The steady growth in the various sectors of aviation necessitates the need for more research on key issues that impact this industry.

I take this opportunity to thank the keynote speakers for their vigorous and expert participation, and the authors of the research papers for their valuable presentations. My appreciation goes to the distinguished sponsors and strategic partners who supported this event as well as the members of the Technical Committee who devoted their time and expertise to ensure compliance with the highest quality standards.

A special note of appreciation to His Highness Sheikh Ahmed bin Saeed Al-Maktoum, Chairman and Chief Executive Emirates Airline & Group and Chancellor of Emirates Aviation University. We remain indebted to his leadership and continuous support.

On behalf of the IAMC-2022 conference committees, it is my privilege and pleasure to welcome you to Dubai. I hope that you find this an excellent opportunity to share knowledge and meet colleagues from around of the world. To the readers of these proceedings, I wish that you find them insightful.

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Keynote Speakers

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The Future of Aviation: COVID-19 Pandemic and Challenges from Emirates Airline Perspective

Steve Allen - Group Chief Executive Officer for dnata
The Future of Aviation: COVID-19 Pandemic and Challenges from dnata Perspective

Colonel Engineer Marwan Mohammad Singel - Director – Dubai Civil Aviation Security Centre, Dubai Police
The Future of Aviation: COVID-19 Pandemic and Challenges from Dubai Police Perspective

Mahmood Ameen - Chief Executive Officer for Emirates Flight Catering
The Future of Aviation: COVID-19 Pandemic and Challenges from Emirates Flight Catering Perspective

Dr. Bijan Vasigh - Professor of Economics and Finance at Embry-Riddle Aeronautical University
The World after COVID-19 and its impact on air transport industry

Delegates' Papers

Understanding the landside passenger experience during the 2022 UK airport delays

Leon Davis and Beverley Boden

Teesside University, United Kingdom

Abstract The COVID-19 pandemic has caused significant impact on the global economy, with a 50.3% loss of global passenger traffic in 2021 (ACI, 2022). However, following the easing of restrictions and lockdowns in 2022, there has been a resurgence in holidaymakers booking air travel. By May 2022, this had increased by approximately 68% of the numbers pre-pandemic (Stewart, 2022). With airports and airlines still understaffed following a fractuous period of furlough and layoffs across the aviation industry during COVID-19, significant delays have increased, particularly in UK airports, which has been reported in media circles. Whilst widespread media interest has focused on specific airports and airline issues, there has been minimal interest in the whole passenger journey, as airlines and airports deflect blame to each other. Using an empirical qualitative approach, this paper focuses on airport passenger experience and the impact of delays on their experiences during the departure journey process at eleven UK airports between March 2022 and August 2022. This advances contemporary literature regarding airport experiences for consumers, but from a post-COVID lockdown perspective. We analyse passenger experiences in a step-by-step process from the *landside* section of the journey, which is the passenger/s arrival into the airport to the point at which they proceed past security.

Key Words *Airport, Experience, Delays, Passengers, Landside.*

1. Introduction

1.1. Overview

Since deregulation of airports in the 1990s, the role and scope of the airport industry has dramatically changed (Graham, 2014; de Neufville & Odoni, 2003; Wattanacharoensil et al., 2016). Since the early 2000s, the airport experience has emerged as an important concept for airport operators. This has been due, in part, to the growing understanding that the airport experience can enhance travel, create airport non-aeronautical revenue, and improve an airport's competitive position (see DKMA, 2014; Wattanacharoensil et al., 2016). Entering the 2020s, there is no doubt that the COVID-19 pandemic has had a seismic impact on the aviation industry overall (see Budd et al., 2020). Across the calendar year of 2021, 4.6 billion less passengers travelled compared to 2019, representing a loss of 50.3% of global passenger traffic. In total, across the first two years of the COVID-19 pandemic, the spread of the virus reduced the number of passengers at the world’s airports by 10.2 billion (ACI, 2022). However, passenger traffic has accelerated in the UK since restrictions eased in 2022. In January 2022, there were 5.8 million international passengers, a third (36%) of the pre-pandemic level of 16.3 million in January 2019. This increased to 15.7 million in May 2022, which is 68% of the pre-pandemic level of 23.0 million in May 2019 (Stewart, 2022). UK passengers have been plagued by flight delays and cancellations since the start of the 2022 summer holiday season, which are often triggered by staff shortages both at airlines and airports.

It is clear that the passenger airport experience has altered exponentially since the start of the COVID-19 pandemic. There are several factors linked to this – but the majority of research and industry consideration has focused on saving airlines, ensuring airports can run operationally through the 2020s and how support schemes can ensure stakeholders in the supply chain can remain efficient and functional as the aviation sector recovers (see Steer, 2020). The UK airport delays in 2022 have had a significant impact on the passenger experience at airports, generating a large number of media interest due to the range of issues within the UK airports at various stages of the passenger journey. This paper focuses on the passenger experience at eleven UK airports from a departure, landside perspective. In agreement with Hsu et al. (2015), the departure process has the greatest impact on the entire operation of passenger terminals. Therefore, we decided to focus our research findings into a critical analysis of the passenger experience during the 2022 UK airport delays.

1.2. Research Objectives

This paper has three primary objectives:

1. Explicate the methodological process involved in collecting passenger data from an in-person qualitative approach.
2. Analyse the impact of airport delays on passenger experiences (landside) at UK airports from an empirical consumer perspective.
3. Establish the key factors which affect the passenger experience during the passenger journey during the 2022 season.

1.3. Justification

This paper explores the consumer experience of passengers (landside) at UK airports the post-COVID-19 lockdowns. This paper elucidates the consumer behavioural practices of airport passengers during the landside section of the departure journey process. As airlines and airports witnessed unprecedented growth as travel restrictions lifted, it became apparent that the industry was not equipped to cope with the immediate resurgence of pre-pandemic levels. This increased demand highlighted significant staffing shortages in many areas, thus impacting the experience of passengers not to mention airport reputation. We were not trying to find out the reasons for the delays or provide a descriptive analysis identifying the stakeholders associated with the delays and the impact on the passenger experience: this has been explored by a variety of media outlets and authors in isolated incidences. We aim to provide an empirical insight that may be able to help the communicative synergies between several stakeholders in the airport process, including the airport owners, airlines, local governments, and regulatory bodies.

2. Literature Review

The customer experience (CX) is a concept that has been closely studied by many companies in recent years, due to CX being one of the most important factors in maintaining a competitive advantage (Bascur and Rusu, 2020). For Lemon and Verhoef (2015), creating a strong CX is one of the leading management objectives. The increasing focus on CX arose because customers now interact with organisations through myriad touch points in multiple channels and media. McColl-Kennedy et al. (2015) highlighted how CX research has become a key focus in academic marketing literature; however, De Keyser et al. (2015) outlined that although a multitude of literature has been published on CX since the late 2000s, the knowledge on CX remains limited. Despite the knowledge on the concept remaining limited, multiple definitions of customer experience exist in academic literature. Schmitt (1999) identified five types of experiences: sensory (sense), affective (feel), cognitive (think), physical (act), and social-identity (relate) experiences. McCarthy and Wright (2004) identified what they termed four threads of experience, linked to technology: the sensual, the emotional, the compositional, and the spatio-temporal. From a retail perspective, Verhoef et al. (2009) defined CX as a multidimensional construct and specifically stated that the CX construct is holistic in nature and involves the customer's cognitive, affective, emotional, social, and physical responses to the retailer. De Keyser et al. (2015, p. 23) described CX as "comprised of the cognitive, emotional, physical, sensorial, spiritual, and social elements that mark the customer's direct or indirect interaction with (an)other market actor(s)".

What is evident from these definitions is that the design, delivery, and management of the CX can be viewed from multiple perspectives: from the firm's point of view, with the firm essentially designing and crafting an experience for the customer to receive (see Berry et al., 2002; Stuart and Tax, 2004); from the customer's point of view (Schmitt 2011); or from a cocreation perspective (see Chandler and Lusch, 2015; De Keyser et al., 2015; Prahalad and Ramaswamy, 2003; Ritzer and Jurgenson, 2010). Overall, scholars and practitioners agree that the total CX is a multidimensional construct that involves cognitive, emotional, behavioral, sensorial, and social components (see Schmitt 1999, 2011; Verhoef et al. 2009). As we are focusing on the customers (passengers) viewpoint of the delivery and management of the passenger journey from an airport-based experience, we would adopt Schmitt's (2011) definition and framework. However, what must be identified, when progressing from CX theory, is the variety of literature focused on the airport passenger experience, which is more aligned to our study area.

Since the early 2000s, the airport passenger experience has emerged as an essential concept for various reasons (see Graham, 2014; de Neufville & Odoni, 2003; Wattanacharoensil, Schuckert, & Graham, 2016). Some of the reasons include the commercialisation, privatisation, and deregulation of aviation in the 1990s, and the understanding that the airport experience significantly enhances travel, creates airport non-aeronautical revenue (DKMA, 2014), and improves an airport's competitive position. Airports in the twenty-first century are not only a transit area within the scope of transportation (Gottdiener, 2001), but they are also particular experience areas including different commercial activities like retail shopping, entertainment services, food, and beverage (see Kiliç and Çadirci, 2022; Lin & Chen, 2013).

In agreement with Kiliç and Çadirci (2022) and Mitsokapas et al. (2021), existing literature regarding the airport experience is continuously expanding and very active. However, research regarding airport experience from consumers' perspectives remain limited (see Kiliç and Çadirci 2022; Popovic et al., 2010; Wattanacharoensil et al 2016). Most of the focus remains on secondary flight passenger data, specific airports as case studies, content analysis, social media datasets, empirical interviews with management in airports, or online customer reviews (Bogicevic, Yang, Bilgihan, & Bujisic, 2013; Gitto and Mancuso, 2017; Lee & Yu, 2018; Mitsokapas et al., 2021; Nghiˆem-Phú & Suter, 2018; Suau-Sanchez et al., 2020; Wattanacharoensil et al., 2017). Though many of the aforementioned studies have examining this issue by using traditional research methods, there is a limited sample of studies which actually collect data in-person from passengers verbally regarding their airport experience *during* the passenger journey.

For passengers, the airport experience starts with preparation activities for the trip until arriving at the final booked destination (Kiliç and Çadirci, 2022; Popovic, Kraal, & Kirk, 2010). As explained in the *Introduction* section above, this paper focuses on the passenger experience at UK airports from a departure, landside perspective. Odoni and de Neufville (1992) reported that, compared with the arrival process, the departure process, which sometimes involves services provided for transit passengers, requires a long time to complete and directly influences the departure time of flights.

On arrival at the passenger terminal, departing passengers have to go through multiple processes including check-in, immigration, and security before boarding while their baggage is sorted and loaded onto the aircraft. In view of the complexity of the departure process, delays are bound to occur when problems, incidents, or accidents arise in any one of the processes or services involved (Hsu et al., 2015). Park and Ahn (2010) explored the check-in operations at airport passenger terminals and how to utilise check-in counters efficiently, which is a major concern facing airport operators and airlines. We understand that attention needs be paid to achieving greater efficiency in the departure process in order to alleviate congestion at airport terminals. Therefore, via our data collection, we collected our data from the surface access/arrival to the airport, check-in, and security perspective to help understand the issues that UK airports have been facing and how this impacted the passenger experience.

3. Methodology

3.1. Research Approach

A collection of qualitative methods were utilised linked to the authors' wider study regarding the impact of COVID-19 on the UK aviation industry. For the purposes of this paper, the primary methods conducted were participant observation and informal conversations with passengers. The use of observation helped to gain more valid or authentic data than would otherwise be the case with mediated or inferential methods (see Cohen et al. 2018), especially when our study was based on a specific time period (spring/summer season 2022) with passengers in the live setting (airports). As passengers ourselves, we could gain live opinion and the only way to do this was to go through the whole airport passenger journey at the various touchpoints (see Figure 1).

Jones (2022) asserted that it is often desirable that observation is used in conjunction with other techniques, such as interviewing or speaking to participants. We completed this via informal conversations during our collection of data with the passengers to provide more thorough meaning to the observations obtained at each airport. Informal conversations have been referred to as 'natural conversations' or 'unstructured' interviews (see Bernard, 2017; Gray, 2021, Patton, 2002). Swain and King (2022) believe that they are different to unstructured interviews, because unstructured interviews are typically pre-arranged by both parties in terms of time and place, and both parties understand the area they are going to be discussing.

We concentrated our data collection into the spring and summer seasons directly following the relaxation of the COVID-19 lockdown restrictions to obtain data in the necessary period during the return to increased passenger footfall. We collected data individually as authors at various airports – we did not collect data together but found via the process of data analysis the themes required to complete the methodological process collectively. We attended UK airports from March 2022 to August 2022 covering eleven airports in the four countries that constitute the United Kingdom (England, Northern Ireland, Scotland, Wales). Individually, we attended the various airports at all contrasting times of day, in what we termed early 00:00 – 06:00, morning 06:00 – 10:00, lunchtime 10:00 – 14:00, afternoon 14:00 – 18:00, evening 18:00 – 00:00. Rather than focusing on a specific type of passenger to engage with, we were open to speaking to any type of passenger and moved amongst the different areas of the airport. This kept our position neutral and ensured our sample was consistent with a normalised airport journey. We did not specifically stick to the check-in area: we conducted observations in all areas of interest, where dwell time was inevitable including security, information desks, retail shopping areas, food and beverage outlets, departure lounges and departure gates (linked to the wider study).

Airport	Respondents
England	
London Heathrow (LHR)	57
Manchester (MAN)	67
Newcastle (NCL)	62
East Midlands (EMA)	38
Leeds Bradford (LBA)	61
Teesside (MME)	50
Northern Ireland	
Belfast (BFS)	44
Derry (LDY)	29
Scotland	
Edinburgh (EDI)	73
Glasgow (GLA)	39
Wales	
Cardiff (CWL)	31

This helped us to analyse the whole airport process as well as avoid bias in searching for specific passengers in places where emotions could be led by what the passenger was facing such as longer queue times and the legacy of COVID-19 restrictions. Expectations of air passengers have become increasingly refined (Jager and Ofner, 2012; Harrison et al., 2012; Deillon, 2013) therefore we needed to consider segments from all areas to understand the perspectives of all different passengers. It must be noted herein that we did not distinguish the differences in passenger type. Whilst Suau-Sanchez et al. (2020) were able to differentiate business and leisure travellers, we did not conduct interviews, and with the length of time for the conversations, we did not have the scope to identify purposes of travel, however it was easy to gauge and differentiate passenger types based on airline carrier and arrival destination.

We conducted informal conversations as opposed to interviews due to the amount of the time the conversations took (an average of 1 – 5 mins), the nature of the discourse and the setting in the airport. The timeframe available to conduct a conversation with the passenger in the natural airport setting left no practical time to build a relationship – a rapport was created, but with no depth. The reason discussion was avoided whilst passengers were engaging with staff was threefold:

- If passengers were receiving unsatisfactory information, they could become very emotive, so their responses may have been unclear or unfocused.
- We did not want to slow down or compromise the passengers' experience progressing through the departure process in line with airport regulations.
- We also did not want to agitate other passengers by slowing down their process of moving through the airport.

Some of the questions we asked the passengers included the likes of 'How did you get to the airport?' 'How long have you been queuing for? 'What was your waiting time through check in?' How long have you been queuing for and were you given adequate information prior to checking in for your flight? We tried to avoid negative connotations in our questioning, although we also asked comparative questions linked to previous experiences pre-COVID and post the primary lockdowns linked to security processes and how they had prepared arriving at the airport before their flight and if this was linked to media or airport/airline recommendations.

Most observers will try to develop a system in which they can record their responses (see Oliver, 2010) – we logged these points via a secure electronic device to maintain discreetness when in the live airport setting. We thought that logging responses would require a pen, paper, or a book/clipboard in a highly active environment, which would have been more obvious to the passengers close to our position in the airport areas could have heightened their reaction and sense of perspective, thus their attitude to engage may have changed. Therefore, we had to be covert in our approach to logging responses. We agreed on using our smartphone/tablets to make response-based notation in various areas of the airport as an observer, but out of the eye line of passengers: those who may have seen our engagement on us on our phone thought we were sending a text or on the internet/social and did not change their expressiveness towards either us or any airport process taking place.

3.2. Data Analysis

In line with this research's interpretive paradigm, a theoretical thematic approach was taken to create themes that were identified at the latent level to generate a flexible analysis of the data collected from the UK airport passengers. Despite many different approaches to thematic analysis (see Boyatzis, 2009; Alhojalian, 2012; Javadi and Zarea, 2016) this research followed Braun and Clarke's (2006) 6-step framework due to the clear and usable structure it provides. Initially, the thematic analysis was conducted by identifying the research aims and then pinpointing emerging themes within the data via colour-coding, underlining, and analysing the text (Veal, 2018; Belotto, 2018). A thematic map proved useful to understand the main themes that emerging from the notations to help identify any sub-themes or relationships between themes. Added to this, lots of relevant data was found in the observations, which aligned with codes and themes derived from the informal conversations; therefore, they were a key part of the data analysis and help to form the basis of the findings.

4. Discussion

Suau-Sanchez (2020) considered whether the impact of COVID-19 would be less intense for the leisure traveller and that we would see a quicker recovery of demand compared to the business travellers. In 2022, passenger demand for leisure travel soared when Covid rules were relaxed, even with increased airfares to the popular destinations pre COVID-19. As travel has increased, the aviation industry has been unable to rehire quickly enough to cope with demand. Layoffs across the entire aviation ecosystem saw some airports as at a standstill as the rapid growth in demand following the relaxation of travel restrictions resulted in mass labour shortages as once dedicated aviation professionals moved on to careers in other sectors (Stewart, 2022). New hires often need to be trained before becoming operational, adding to disruptions.

We explored the passenger experience and the impact of delays on their experiences during the departure journey process at eleven UK airports between March 2022 and August 2022. In recent decades, airports have undergone huge technological advances to create a more seamless experience, yet for most passengers, this is simply part of the experience with the expectation airports will do more to elevate experiences, particularly post COVID-19. Indicative results show that most passengers spend a high proportion of their landside dwell time experiencing processing activities. The findings provide an understanding of passenger landside experiences and how they can be improved. We have charted the overall passenger process (see Figure 1 below) in a variety of touchpoints from surface access to passengers boarding an aircraft in our wider study, but for the purposes of this paper, we focused on the 'landside' section of the passenger journey:

Figure 1: Key touch points during the passenger journey through the airport process.

4.1. Landside Key Findings

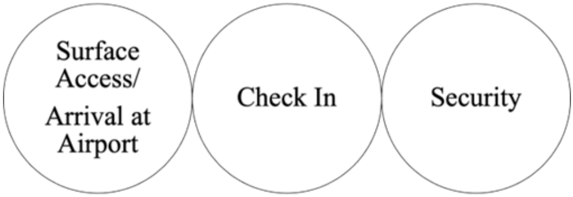

Figure 2: Landside process explored during the study.

This section focuses on the key findings from our landside data collection process. This is presented in 3 sections (see Figure 2) based on the landside process – surface access, arrival at airport, check in, and the security checkpoint area. Despite the landside area of an airport playing a critical operational function in the timely departure of an aircraft, this is an area that is overlooked. As airports begin to resume normal services our research highlights the functionality and satisfaction levels of this area as crowded check in halls, longer queues and a significantly reduced workforce are becoming commonplace. It is evident from the findings that airports need to rethink their approach to space, resources and passenger experience should passenger numbers return to pre-COVID-19 levels.

Skytrax, a global quality ranking programme which allows passengers to rate airports, including queuing times has become a global benchmark of quality evaluation and an indicator of service excellence in aviation. Recent findings (Sktyrax, 2022) revealed that passenger experiences at customer touchpoints and efficiency in landside areas of airports requires significant improvement at some UK airports. The study highlighted a clear rationale for airports to consider space optimisation and fixed resources as legacy airlines often benefit from open space to contain passengers on check in, but at smaller, regional airports, this hall allocation layout is outdated, labour intensive and does not incentivise better throughout for passengers.

4.2. Arrival at Airport

In regard to surface access, there are a number of issues that are affecting the passenger experience - a rising number of train strikes across the UK; airport car park price increases; and a hike in hotel room prices in the regions around airport locations during industrial action. During our observations, these issues resulted in airport terminals becoming ‘sleeping halls.’ Passengers at London Heathrow commented that missing connecting flights had left them with no option but to sleep in the airport because the price of the hotel would not be covered by the proposed compensation offered by the airlines.

Time was one of the most significant factors in the passenger experience that has changed post COVID-19 lockdowns. Airport warnings and media representation of this created panic which led to more passengers turning up earlier and earlier resulting in crowded terminals, a lack of services and longer queues. Norris (2022) explained the need for airports to convey clear messaging to passengers amidst mixed messaging across global media channels that encouraged passengers to arrive for some flights up to eight hours ahead of the scheduled departure Travel Weekly (2020). Focusing on London Heathrow, Topham (2022) highlighted the airline sector's turmoil as being self-perpetuating: huge queues grow with anxious passengers turning up ever earlier for flights. At Manchester, Liverpool, Leeds-Bradford and East Midlands airport, passengers stated that they had arrived for flights departing between 7-8am between 2am and 3am. Topham (2022) explained an example of a passenger turning up 9 hours before a flight due to the wider travel disruptions of trains getting to the airport. In some instances, passengers would arrive at least 3 hours ahead of departure to find their flight had been cancelled due to staff shortages or a delayed departure causing more bottlenecks in an area that is for processing not consuming. Queues for check-in desks and security checkpoints would commonly snake inside and outside airport entrances and swell towards check-in areas.

4.3. Check-In

Park and Ahn (2010) explored the check-in operations at airport passenger terminals and how to utilise check-in counters efficiently, which is (and was) a major concern facing airport operators and airlines at the time of their research. Whilst pre COVID-19 some airlines had 10-20 check-in desks open, our observations at UK airports in 2022 found that it was common practice to experience 2 check-in desks open for long-haul airlines with multiple flights leaving around the same time. Therefore, passengers had to wait longer than usual to check in, as existing staff were required to train inexperienced staff and process passengers simultaneously.

Inadequate communication for passengers leading to increased levels of dissatisfaction at each of the airports we visited. Communication was lacking due to a lack of staff to provide communicative information. Typically, passengers who arrived at airports to delayed or missing connecting flights, would be directed to online or phone-based contacts, as opposed to airline support in the airport. A lack of staff at critical earlier touchpoints in the landside process led to further delays. A key example of this was in the luggage process, namely oversized baggage at both Manchester Airport and Stansted Airport. The oversized baggage area was typically understaffed or the process to check oversized baggage such as motorbikes, golf bags or ski equipment took up to 3 hours to be processed. This led to bottlenecks in the check in area that mixed in which oversized baggage queues and required airport staff to then inform the passengers with imminent departure times that they needed to be processed immediately. Staff would then direct these passengers to the front of the security checkpoint, which led to increased delays for other passengers.

4.4. Security

Airports face several challenges when processing passengers, yet despite significant investment in airport security and passenger screening, post 2006, (Henderson, 2008) there is call for greater automation and quicker screening processes for an enhanced passenger experience at larger UK airports. Our observations found security scanning checkpoints being manned by less staff and a number of security lanes not being used. Whilst this is not uncommon at airports across the globe, this caused a backlog of queues. This was exacerbated by the unavailability to book of fast-track security lanes at certain airports (for e.g., Manchester Airport) for a number of weeks at peak times, before online issues meant the fast-track availability was fully suspended (Cox, 2022).

There appeared to be a contrast in views, observations at Teesside International Airport and Newcastle International Airport. These differed due to terminal layout (the distinct separation of check in and security zones) passenger numbers and the staggered departure of flights. Delays and queues were minimal at Teesside Airport due to a recent £3million overhaul of security and the introduction of new scanners (Teesside International Airport, 2022) resulting in passengers being processed much more quickly.

Airports are constantly horizon scanning to improve the passenger experience and in the wake of COVID-19, airport operators need to re-evaluate their operational priorities. Correa (2020) suggested that airports need to consider wider revenue streams for passengers to enjoy an immersive experience landside rather than this zone being used simply for processing passengers. Many people view the airport function as simple and singular, however, the landside area of a terminal should be (and can be) viewed as an opportunity to make an impression, wow passengers, and generate income. Based on the airports we visited, airports that formed part of the sample provided an enjoyable experience. Newcastle had appropriate signage, an array of facilities and staff to engage with passengers.

4.5. Summary

Our data found that departure times was key to the UK landside passenger experience in the summer season of 2022. The morning (06:00 - 10:00) flight times was the time period when the most significant congestion occurred in terms of surface access, check-in and security, which passengers considered the critical element of the passenger experience in the departure journey. Whilst this is not prescient information, it was notable that certain airports (or airlines in regard to ground crew staff) have not tried to focus their staffing or recruitment efforts into this time period. Airports need to focus more on the customer service to convince passengers to fully immerse themselves in the airport experience, as the issues with the landside journey are deterring passengers from spending disposable income in the airside section of the airport (for e.g. food, retail, beverages). Pent-up demand since lifting COVID-19 restrictions has meant that airlines need to work more collaboratively with airports and ground handling agents to ensure flights depart on time. In keeping with the exacting standards of service, synonymous with air travel, airlines must provide up-to-date information, be transparent in their communication and minimise disruption should delays occur. Airlines have an obligation to inform passengers of their consumer rights when things go wrong and if necessary, be compensated in reasonable time. Collaboration or more effective communication between airports and airlines, alongside governmental engagement, will be vital to the improvement of these passenger services across the UK in the 2023 season.

Overall, we have found that:

- Informal conversations are an important data collection method with passengers that other scholars should adopt when exploring live airport research as opposed to interview methods that cannot capture customer feelings in the specific moment of the passenger journey.
- The key factors which affect the landside passenger experience during the passenger journey during the 2022 season were the specific flight departure time and the limited staff available at check-in and security processes.
- Advancing this, departure times were key to the UK landside passenger experience in the 2022 summer season; morning flight times were the most significantly congested time periods which the passengers and media had focused upon.

- More joined-up consultation is needed between the airports, airlines and governments to ensure a robust resilience plan supports the aforementioned stakeholders should a shock like COVID-19 occur in the future.

5. Conclusion

The prime motive of this paper was to analyse the landside passenger experience during a period of disruption post COVID-19 at a range of UK airports during 2022. A central issue was that UK airlines and airports were able to cut their workforces earlier in the COVID-19 pandemic, while their competitors in many other European markets maintained a greater share of employees on their payrolls even when air traffic fell significantly. The tightening UK labour market (still feeling the ongoing effects of Brexit) and the rapid post-pandemic traffic recovery, spurred by pent-up leisure demand, mean that UK airports are experiencing significant delays and disruptions due to staff shortages. We hope that this paper allows researchers to constructively rethink the experience passengers have in landside areas and how effective scenario planning, appropriate staffing, robust staff training and processes can shape how passengers are processed with confidence. This research highlights the need for further comprehensive studies to examine factors associated with passenger movements and behaviour in landside areas within airport terminals during a period of disruption that can severely affect operations, profit, and reputation.

With the nature of the study and the way that we approached the passengers, it was complex to differentiate the type of travellers. What we noted was that the factors that impact the overall customer experience (and more specifically, airport passenger experience) of travellers is varied due to the different characteristics and demographics of the passengers. Future studies could focus on specific types of passengers and the impact on the landside experience on their journey. We understand that the content in this paper does not cover all UK airports, but we aim to increase our sample size linked to our wider study on the impact of COVID-19 on the passenger experience in airports across a longer timespan to cover the full summer season. Whilst this paper has explored the landside aspect of the airport experience, we understand that there are lots of other factors involved within the airside experience that needs to be explored in future research. We also acknowledge that there are a number of factors that need to be considered that we could not cover linked to discourse with senior management in the UK aviation industry, governmental officials, and specific airport management that could elucidate some of reasons for the issues passengers have encountered in UK airports in 2022.

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Quantifying the Impact of COVID-19 on Domestic Aviation in the USA from 2020-2021

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Abstract Trends in key passenger and cargo metrics are established for domestic US aviation from 2011-2021, using primary operational data sourced from the US Bureau of Transportation Statistics. The downturn that resulted from the spread of COVID-19 during 2020 and 2021 is assessed here by comparing the actual reported data against extrapolated data representative of the normal growth and performance that would otherwise have occurred in the absence of COVID-19. A modified Seasonal Naïve Model, implemented in MS Excel, facilitates this extrapolation. The sum of the monthly differences between the reported data and the extrapolated data allows the impact of COVID-19 to be fully quantified, and thus provides a benchmark to guide future risk mitigation and emergency planning strategies.

Key Words *Aviation, Bureau of Transportation Statistics, COVID-19, Domestic, USA.*

1. Introduction

1.1. Background

In late 2019 an infectious disease caused by a new coronavirus named SARS-CoV-2, commonly referred to as COVID-19, was first reported in the Chinese city of Wuhan and quickly spread worldwide; a few months later it was pronounced a pandemic by the WHO (World Health Organization 2020). Governments around the world responded with various protective measures aimed at minimising the risk of transmission and avoiding a public health crisis, e.g., physical or social distancing, quarantining, ventilation of indoor spaces, wearing face masks or coverings in public settings, international travel bans, lockdowns, and working from home. These disease mitigation measures severely affected the global economy and financial markets due to disruptions in the transportation, service, and manufacturing industries. Foremost amongst these hard-hit industries was Aviation and its associated supply chain – as just one example amongst the countless that could be given, it is estimated that since early 2020, when the pandemic essentially halted global air travel, at least 68 airlines have either entered or exited bankruptcy (Bloomburg 2022).

1.2. Aim

In order to quantify the effect COVID-19 has wrought on the aviation industry it is necessary to have access to genuine operational data. Of the three largest domestic aviation markets in the world - the USA, China, and Europe - only the US Bureau of Transportation Statistics publishes such primary data in the public domain (Bureau of Transportation Statistics, 2022a). Hence this work is limited to a study of the impact of COVID-19 on the US domestic aviation industry, focusing on passenger and cargo services; the consequences of this particular downturn will be examined by capturing the changes in key market indicators. Such a study then provides a baseline against which the cost and effort of implementing future risk mitigation strategies and emergency response measures may then be judged.

1.3. Significance

Due to the very recent nature of the pandemic, quantifying the effect of COVID-19 on domestic US aviation has received little formal attention. The only relevant extant work is due to Hotle and Mumbower (2021), and Airlines for America (2022). In the former case, the researchers selected a rather short time range for assessment, based on data ranging from January 2019 to May 2020. The changing trend pre- and post-COVID-19 could not be identified without a knowledge of the previous years' data, and their work only reviewed a single year, even though the worst of the pandemic lasted for more than two years. Airlines for America (2022) have commendably tracked a wide range of key aviation metrics from 2020-2022, but all their reported comparisons were related to 2019 data. Hence the work reported here is the first comprehensive assessment and prediction of the losses incurred in the US domestic passenger market and the serendipitous gains made in the US domestic cargo market. The significance of this work is simple - once the magnitude of the losses can be quantified, this provides a solid baseline against which a robust emergency management plan can be prepared to ensure domestic aviation businesses can continue to operate should another such pandemic suddenly eventuate.

2. Methodology

Most commentators have compared key data from the COVID-19-affected years with corresponding data from 2019, just before the pandemic struck the USA (Airlines for America 2022). This provides useful information and also allows simple percentage differences to be obtained, which helps explain the extent of the downturn. However, it references 2019 data as the baseline, which may not be truly representative since some organic airline growth would have occurred during 2020 and 2021 had COVID-19 not happened. Hence, the authors contend that it is possible to extrapolate the trends in the key data from 2011 to 2019 to give a projected monthly estimate for both 2020 and 2021 under the assumption of normal growth and performance in the absence of COVID-19. This then allows a more direct comparison of the downturn in terms of how the industry is currently performing to how it would normally have been expected to perform.

To forecast/predict the patterns of US domestic aviation passenger and cargo movements, a time series analysis must be chosen that can account for the seasonal variation present, and in the interests of simplicity and ease of implementation using MS Excel 2016, the authors opted to use a basic but nonetheless proven technique based on the Seasonal Naïve Model (Armstrong 2001). Data drift was accounted for using simple linear regression, as explained in Section 3.1. Whilst there are many other sophisticated methods applicable to nonstationary data forecasting, such as Box Jenkins' Auto Regressive Integrated Moving Average (ARIMA) methodology (2015), or Chen and Hsu's Fuzzy time series (2004), these were considered overly complex for the purposes of this work and did not justify the extra effort that would have been involved in their implementation.

The data time range considered here for extrapolation purposes was limited to the nine years of data preceding COVID-19, namely 2011-2019, which yielded relatively stable trends across all key indicators – there were no major "events/downturns" during this time, such as the dot-com bubble, 9-11 terrorist attack, SARS, MERS, or the global financial crisis. The Seasonal Naïve Model employed here assumes these existing data patterns will continue into the future, with the most accurate forecasts being confined to the short term, i.e., the years 2020 and 2021. (For comparisons with the actual data, information from the years 2020 and 2021 was also gathered). The primary data regarding domestic U.S. aviation are obtained from the BTS Form 41 T-100 Domestic Market (U.S. Carriers) and T-100 Domestic Segment (U.S. Carriers) for analysis (Bureau of Transportation

Statistics, 2022b). Data extraction has occurred at a *monthly* level over all 11 years of interest to ensure a high level of granularity has been included in this work.

To quantify the effect of COVID-19 on domestic US aviation, eight key indicators are picked or derived using the primary data from the BTS T-100 database (Bureau of Transportation Statistics, 2022b) to assess passenger and cargo movements. (The authors do not have access to airline financial reports or other customer confidential information, and so cannot report on the financial losses or gains incurred). The eight metrics shown in Table 1 capture all the essential information about passenger and cargo activities:

Metric	Description	Reference source
Passenger:	Passenger Numbers	BTS T-100 Domestic Market (U.S. Carriers)
	Available Seat Miles (ASM)	BTS T-100 Domestic Segment (U.S. Carriers)
	Revenue Passenger Miles (RPM)	
	Passenger Load Factor (Pax LF)	
Cargo:	Cargo Tonnage	BTS T-100 Domestic Market (U.S. Carriers)
	Available Ton Miles (ATM)	BTS T-100 Domestic Segment (U.S. Carriers)
	Revenue Ton Miles (RTM)	
	Cargo Load Factor (Cargo LF)	

Table 1: Metrics used to assess the impact of COVID-19 on US domestic aviation.

It is noted that this work is limited to the timeframe starting with the emergence of COVID-19 in the USA in March 2020 until the end of December 2021; at the time of writing, no data has yet been reported in the BTS for the first quarter of 2022.

3. Key Findings

3.1. Passenger Metrics (Passenger Numbers)

Passenger services can be divided into two categories: scheduled and non-scheduled. Since over the three years 2019-2021 the non-scheduled passenger numbers account for less than 1% of the scheduled passenger numbers, there is little to be gained from treating these as separate entities; hence total passenger numbers are reported herein.

The Seasonal Naïve Model, which accounts for data drift using simple linear regression, is now explained, with reference to a specific example. To predict the number of US domestic passengers travelling by air in March 2020, assuming no COVID-19 event, data records for total passenger numbers are assembled for the March of each year from 2011 to 2019 inclusive. A linear regression analysis is then applied to this data using MS Excel's TREND function (Svetlana 2020), and then the March 2020 estimate can be extrapolated. This now forms a new data point, which, when used in conjunction with all the previous data, enables one further extrapolation to give a second point for 2021. This process is repeated for April's data and so forth for each month to build up an estimate of the travel data throughout 2020 and 2021. This approach has sufficient resolution to capture all the seasonal variations and other fluctuations exhibited by the normal non-COVID-19 data from 2011 to 2019. Table 2 provides BTS data from the years 2011-2021 and Figure 1 shows how the estimated passenger numbers would have had a gradual upward trend (drift) in the absence of this pandemic.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	46,501	43,842	55,895	53,074	56,176	57,993	60,548	57,651	51,267	54,406	51,916	51,745
2012	47,258	46,592	56,418	53,891	55,929	58,095	59,872	58,876	50,390	54,027	52,068	51,328
2013	47,986	45,881	56,739	53,401	56,738	58,154	59,481	58,317	51,007	54,942	50,749	54,533
2014	48,146	45,669	57,971	55,403	58,047	59,451	61,928	59,958	52,762	57,334	52,804	55,676
2015	49,892	47,303	59,726	57,852	60,415	61,978	65,297	62,934	56,217	61,125	57,351	58,032
2016	52,626	51,238	61,740	59,022	62,891	64,888	66,266	63,657	58,864	61,965	59,487	59,339
2017	54,274	51,222	64,151	61,263	64,608	66,890	68,700	66,832	57,390	64,885	62,134	61,567
2018	55,983	54,233	66,830	64,718	68,002	70,417	72,666	70,493	60,679	67,301	64,899	63,793
2019	58,196	55,826	70,412	67,100	71,528	72,928	75,429	72,906	64,233	70,194	65,102	69,951
2020	61,849	60,071	34,528	2,896	7,888	16,185	22,995	24,520	23,967	28,178	26,428	27,386
2021	24,451	24,589	39,492	43,970	52,896	60,286	66,919	60,819	54,147	60,840	60,037	59,747
2020*	61,849	60,071	**70,089**	**67,408**	**71,443**	**73,389**	**75,633**	**73,230**	**64,334**	**71,310**	**67,447**	**69,103**
2021*	**61,464**	**59,289**	**71,887**	**69,206**	**73,413**	**75,383**	**77,644**	**75,174**	**66,027**	**73,435**	**69,458**	**71,235**

Table 2: US Carriers Domestic Passenger Numbers (x 10^3). * Estimated data.

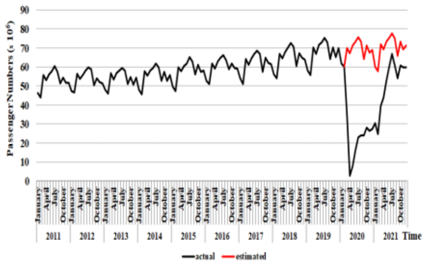

Figure 1: US Carriers Domestic Passenger Numbers, Actual and Estimated, by Month, 2011-2021.

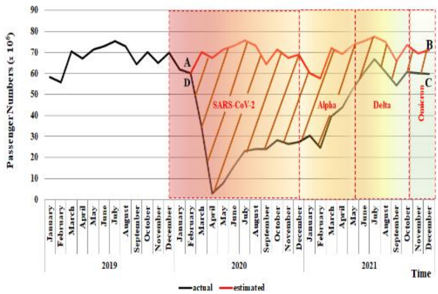

Figure 2: US Carriers Domestic Passenger Numbers, Actual and Estimated, from 2019-2021, and the main phases of COVID.

It is evident that a dramatic drop in actual passenger numbers appeared after the breakout of COVID-19 in the USA, around March 2020. Figure 2 shows the 2019-2021 region magnified from Figure 1, overlaid with the main phases of the different COVID-19 variants that were present in US society. The trend in passenger numbers agrees with that found by other authors (Atems & Yimga 2021) and clearly illustrates how the emergence of COVID-19 impacted US domestic aviation passenger transport. In the second quarter of 2020, passenger numbers suffered a precipitous decline of 95% compared to the previous year's data, followed by the start of a long and gradual recovery.

Thus, the difference between the actual data and the estimated data (i.e., the hatched area A-B-C-D shown in Figure 2) can be compared on a month-by-month basis and then the sum total reduction in passenger numbers computed. (This methodology is applied to all the remaining metrics). The result (see Figure 7 for further details) shows the US domestic aviation industry suffered a devastating loss of 715.6 million passengers from March 2020 to December 2021.

3.2. Other Passenger Metrics (RPM, ASM, and Passenger LF)

Available Seat Miles (ASM) is a measure of airline capacity and is computed by taking the aircraft miles flown on each segment multiplied by the number of seats available for revenue use on that segment. Revenue Passenger Miles (RPM) gives the number of statute miles that all revenue passengers were transported by the airline. It is calculated as the number of revenue passengers multiplied by the total distance travelled (Bureau of Transportation Statistics 2022b). The passenger Load Factor (LF), which is obtained by dividing RPM by ASM, presents a clear picture of the demand and supply ratio. Table 3 presents the numerical data for actual RPM, ASM and LF for the years of interest 2019, 2020 and 2021; Figure 3 plots these trendlines, and it is evident that the normal passenger LF during 2019 was relatively stable between 80%-90%. It is noticeable that there is always a small gap between demand (RPM) and supply (ASM), with demand always leading supply. However, after the breakout and spread of COVID-19 in the USA, the gaps between ASM and RPM became irregular, and the LF value plummeted to just 13% in March-April 2020 (its lowest value since records began) before recovering in an erratic fashion to around 82% by December 2021.

Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ASM_{2019}	69.0	63.0	75.9	72.6	75.6	76.8	80.2	79.2	71.0	75.2	72.5	76.6
RPM_{2019}	54.5	51.5	65.5	62.1	65.9	68.5	71.4	68.3	58.4	63.5	59.4	65.5
LF_{2019}	0.79	0.82	0.86	0.86	0.87	0.89	0.89	0.86	0.82	0.84	0.82	0.86
ASM_{2020}	72.8	68.8	65.2	19.6	17.3	24.9	40.5	43.2	36.3	40.9	44.0	45.6
RPM_{2020}	57.8	55.5	32.6	2.6	6.7	13.9	20.1	21.2	20.6	24.5	23.8	25.2
LF_{2020}	0.79	0.81	0.50	0.13	0.39	0.56	0.50	0.49	0.57	0.60	0.54	0.55
ASM_{2021}	42.6	38.1	54.1	55.1	61.7	67.8	73.8	72.2	66.7	69.6	68.9	69.9
RPM_{2021}	22.5	22.6	36.9	41.1	49.8	57.8	64.7	58.5	50.3	56.1	55.9	57.2
LF_{2021}	0.53	0.59	0.68	0.75	0.81	0.85	0.88	0.81	0.75	0.81	0.81	0.82

Table 3: ASM (x 10^9), RPM (x 10^9), and Pax LF for the years 2019, 2020 and 2021.

After COVID-19 started to spread in the USA in March 2020, the national government and many states issued travelling restrictions and lockdowns, which caused a dramatic decline in passenger air traffic. By April 2020, both the RPM and ASM had plummeted to 2.56 billion and 19.56 billion respectively (drops of over 73% and 96% compared with April 2019 data). People were ordered to stay at home to reduce the spread of the virus, and other new rules, including the need for COVID testing, mask-wearing and varying quarantine requirements from different states, added to the complexity of domestic travel (CDC 2022).

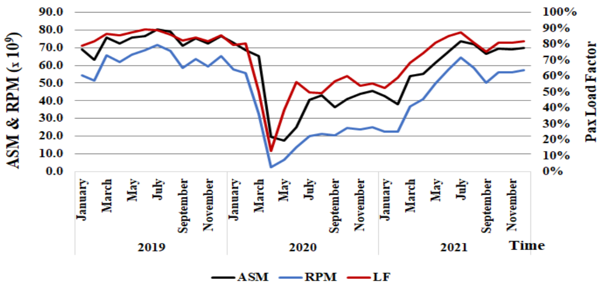

Figure 3: Trendlines for RPM, ASM, and Passenger LF from 2019 to 2021.

From mid-April 2020 to June 2020, although the number of COVID-19 cases kept increasing, both the RPM and ASM improved, largely as a result of a generous bailout plan passed by the U.S. Congress for the commercial airline industry (CNS 2020) and peoples' renewed willingness to travel and help alleviate their sense of confinement (Miao 2022). The year 2021 saw three waves of new COVID-19 variants sweep over the USA, and with each new variant there was a corresponding short-term decline in the demand for air travel, followed by a general improvement. By the end of 2021, the passenger LF had returned to 82% and domestic aviation appeared to have recovered approximately to its pre-pandemic levels. Seasonality effects in the RPM and ASM values had also started to become more apparent, suggesting US domestic passenger travel had returned to some level of normality.

3.3. Cargo Metrics (Tonnage)

Air cargo is defined as the sum of express, freight and mail carried by air. The Bureau of Transportation Statistics (2022b) identifies four main categories of air cargo: Scheduled services 'F' (Passenger aircraft carrying cargo in the belly hold) and 'G' (dedicated all-cargo aircraft); and non-scheduled services include 'L' (Passenger aircraft carrying cargo in the belly hold) and 'P' (dedicated all-cargo aircraft). Space does not permit a detailed investigation of each individual service category, so only the total air cargo tonnage and its associated trends will be examined and presented here. The short ton, equivalent to 2,000 lb, is used in this work to determine general tonnage, Available Ton Miles (ATM) and Revenue Ton Miles (RTM), noting the raw data from the BTS is presented in pounds weight (lb). Table 4 provides total cargo tonnage data from the years 2011-2021. Figure 4 shows the actual data trend line used to extrapolate and hence estimate the total air cargo tonnage carried throughout 2020 and 2021 following the methodology described in Section 2; Figure 5 gives a close-up view from 2019 to 2021 overlaid with the main phases of the COVID-19 variants.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	793	772	935	855	825	888	833	873	858	856	864	974
2012	785	816	904	804	888	866	814	890	834	886	891	923
2013	866	783	876	829	886	850	849	916	829	952	884	981
2014	878	795	884	901	906	857	919	905	864	970	884	1,038
2015	885	836	905	922	901	902	940	897	941	992	884	1,110
2016	885	833	990	942	913	983	932	995	989	978	1,007	1,153
2017	925	873	1,060	956	1,011	1,036	980	1,089	1,022	1,087	1,121	1,212
2018	1,022	950	1,103	1,004	1,101	1,083	1,046	1,141	1,065	1,149	1,120	1,213
2019	1,084	957	1,099	1,081	1,150	1,088	1,111	1,141	1,035	1,170	1,099	1,267
2020	1,090	977	1,133	1,115	1,199	1,226	1,285	1,224	1,262	1,340	1,257	1,474
2021	1,236	1,033	1,325	1,277	1,240	1,275	1,306	1,276	1,280	1,316	1,293	1,509
2020*	1,090	977	**1,116**	**1,071**	**1,137**	**1,113**	**1,110**	**1,171**	**1,097**	**1,198**	**1,158**	**1,315**
2021*	**1,162**	**1,031**	**1,145**	**1,101**	**1,173**	**1,146**	**1,145**	**1,209**	**1,128**	**1,236**	**1,195**	**1,358**

Table 4: US Carriers Domestic Total Cargo Tonnage (Short Tons x 10^3). * Estimated data.

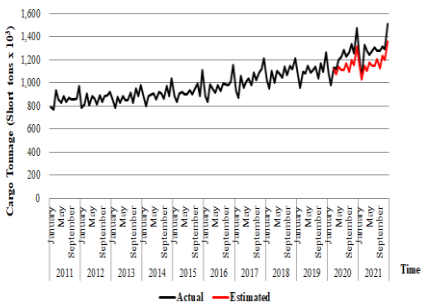

Figure 4: Total air cargo tonnage (short tons), Actual and Estimated, by Month, 2011-2021.

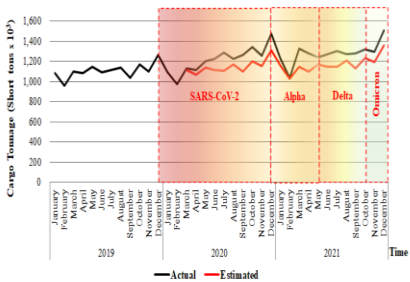

Figure 5: Total air cargo tonnage (short tons), Actual and Estimated, from 2019-2021, and the main phases of COVID.

It is immediately evident that throughout both 2020 and 2021 air cargo actually increased slightly every month compared to how it would have behaved in the absence of COVID-19 and continued to reflect the seasonal spikes in air cargo movements seen every December due to Thanksgiving and Christmas. Unlike Meng's study (2021) which said the lowest point of air freight turnover in the U.S. was in April 2020, the current work agrees better with the results of Suau-Sanchez *et al* (2020), namely, that air cargo has continually improved due to the transportation of masks, personal protective equipment, ventilators, vaccines and other necessities. In addition to medical supplies, once the lockdowns and restrictions on movement became widespread, by mid-2020 the demand for contactless online shopping for daily necessities had increased significantly and as a result, the actual cargo tonnage has always surpassed the estimated value since the pandemic began.

3.4. Other Cargo Metrics (RTM, ATM, and Cargo LF)

Available Ton Miles (ATM) is computed by multiplying the aircraft miles flown on each segment by the number of tons of aircraft capacity available. A Revenue Ton Mile (RTM) is one ton of revenue traffic, (passengers, freight, mail), transported one statute mile. Passenger weights are ***excluded*** from the contributions to cargo data from service classes F and L. ATM shows the capacity cargo carriers provided, while RTM illustrates the real air cargo demand. By dividing the total RTM by the total ATM, the overall Cargo Load Factor is obtained. Table 5 presents the numerical data for actual RTM, ATM and LF for the years of interest 2019, 2020 and 2021; Figure 6 plots these trendlines. ATM and RTM are displayed in units of short tons and statute miles.

Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ATM_{2019}	5.848	5.100	5.643	5.307	5.692	5.415	5.670	6.604	5.716	6.168	6.170	6.969
RTM_{2019}	1.301	1.132	1.344	1.316	1.380	1.327	1.342	1.385	1.282	1.423	1.400	1.565
LF_{2019}	0.222	0.222	0.238	0.248	0.242	0.245	0.237	0.210	0.224	0.231	0.227	0.225
ATM_{2020}	6.386	5.791	7.999	5.264	4.644	4.932	6.390	6.549	5.855	6.284	6.767	7.763
RTM_{2020}	1.299	1.145	1.435	1.434	1.565	1.592	1.639	1.593	1.618	1.711	1.679	1.877
LF_{2020}	0.203	0.198	0.179	0.272	0.337	0.323	0.256	0.243	0.276	0.272	0.248	0.242
ATM_{2021}	6.606	5.519	6.700	6.119	6.213	6.124	6.527	6.769	6.883	6.820	6.774	7.789
RTM_{2021}	1.592	1.327	1.719	1.688	1.663	1.675	1.710	1.678	1.656	1.731	1.719	1.971
LF_{2021}	0.241	0.240	0.257	0.276	0.268	0.274	0.262	0.248	0.241	0.254	0.254	0.253

Table 5: ATM (x 10^9), RTM (x 10^9), and Cargo LF for the years 2019, 2020 and 2021.

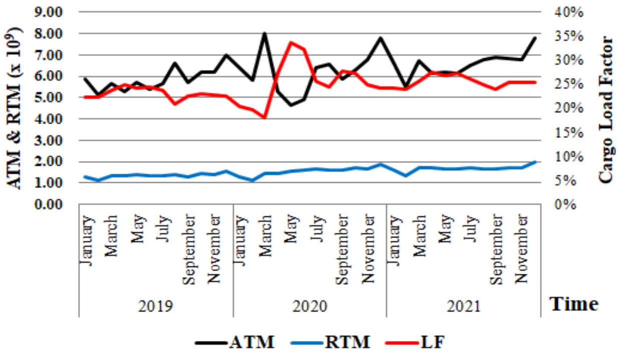

Figure 6: Trendlines for RTM, ATM and Cargo LF from 2019-2021.

After COVID-19 started to spread in the USA in March 2020, the lack of belly capacity (especially in class F services) caused by the widespread cancellation of domestic commercial passenger flights contributed significantly to the sudden decline in cargo ATM in March-May 2020 (see Figure 6), whilst the RTM performed showed a slight increase, attributed to the transportation of Personal Protective Equipment and the locked-down population starting to make online purchases. This had the effect of causing the Cargo LF to spike, and it reached a momentary peak of 34% towards the end of the second quarter of 2020. Things improved after June 2020, as domestic commercial flights resumed and hence the available belly capacity (class F) increased; hence the ATM improved somewhat but did not quite recover to its corresponding 2019 values. In 2021, both ATM and RTM increased somewhat, which can be explained by two factors. Firstly, as seen in Figure 2, as the domestic commercial passenger service gradually recovered, the available ATM afforded by class F further increased, resulting in steady growth in the total available ATM. Secondly, the transportation of vaccines and other medical supplies by all-cargo services (G & P), especially those requiring cold storage temperatures, was significant. Promotion of a third booster shot to guard against newly mutated COVID-19 variants further increased the need for vaccine deliveries. The FAA COVID-19 Vaccine Air Transport Team (FAA 2020) also made a lasting contribution to both ATM and RTM growth in 2021. By the end of 2021, the increased rate in ATM was around 11% while that of RTM was around 25% compared with 2019 values. The Cargo LF historically has varied between approximately 20%-25%, but after some fluctuations during the pandemic, had, by the end of 2021, settled to a more stable value around 25%, reflecting the continued increase in demand and available capacity for air cargo movements which in turn have largely been driven by people's preference to continue shopping online.

3.5. Summary of Actual vs Estimated metrics: Passenger numbers, RPM, Cargo tonnage, RTM

In Section 2, the authors explained how it was possible to obtain an accurate forecast or forward estimate of a given trend, based on an extrapolation of the previous 9 years of data. By considering the graphs of passenger numbers and RPM for passenger data, and the corresponding graphs of total cargo tonnage and RTM for cargo data, the difference between the estimated trend and the actual trend (i.e., the area between the two trend lines) quantifies the actual loss (or gain) in business experienced by US domestic aviation. For each metric, the difference in the estimated and actual data for each month, from March 2020 to December 2021, has been calculated and then summed month-by-month to determine the total area between the two trend lines. See Figures 7-10 below. These simple figures provide graphic evidence of the major disruption that COVID-19 wrought on US domestic aviation and quantify, in broad terms, the losses and gains experienced by the passenger and cargo sectors respectively. To try to translate the losses in passenger numbers and RPM into monetary terms is almost impossible, simply because by not travelling on a particular route at a particular time, the full extent of a single passenger's economic impact on the wider supply chain will never be known.

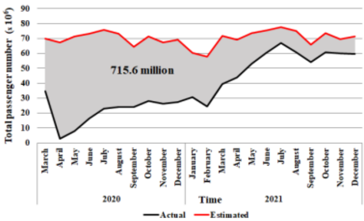

Figure 7: Loss in passenger numbers Mar 2020-Dec 2021.

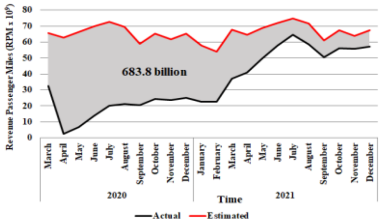

Figure 8: Loss in RPM Mar 2020-Dec 2021.

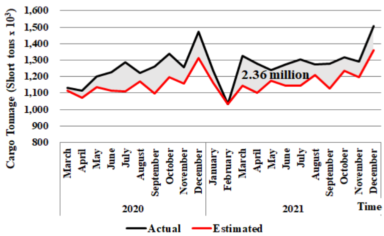

Figure 9: Gain in cargo tonnage Mar 2020-Dec 2021.

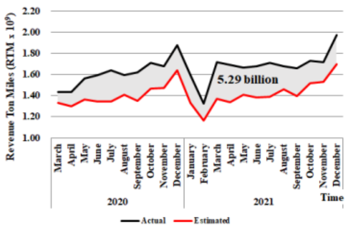

Figure 10: Gain in cargo RTM Mar 2020-Dec 2021.

4. Conclusion

The research has considered both the passenger and cargo sectors of the U.S. domestic aviation market and gathered all the relevant data from the years 2011 to 2021. This has enabled a meaningful comparison to be made between the pre-pandemic data in 2019, estimated data projected into 2020 and 2021, and the actual recorded data as published by the US BTS (Bureau of Transportation Statistics 2022b). Overall, total passenger numbers suffered a loss of 715.6 million, and 683.8 billion RPM, as a result of travel restrictions and public safety concerns during the period of interest. In contrast, the total cargo tonnage serendipitously increased by 2.36 million tons and RTM experienced an increase of 5.29 billion ton-miles, both of which are attributed to transporting medical equipment and vaccines, online shopping packages and the re-purposing of some passenger airlines as freight carriers. These key metrics thus quantify the impact of COVID-19 on the US domestic aviation industry and give some indication of the colossal loss of passenger revenue and the significant gains in cargo revenue.

Although the losses (or gains) determined here have occurred at a macroscopic level across the entire domestic aviation industry - and some airlines and businesses will have been more impacted than others - they do not extend to the social and economic cost of all the associated redundancies, reduced work shifts, and difficulties of attracting skilled workers back into the aviation workforce post-pandemic. Clearly, COVID-19 has caused a major disruption to US domestic aviation and the lasting impact resulting from this pandemic will be felt for many years to come. Hence it is incumbent on airlines, industry, state governments and the US federal government to work together and develop longer-term strategic thinking in terms of risk mitigation planning and emergency response measures; sadly, it comes as no surprise that government and airline expenditure has always shown a bias towards funding response activities over mitigation. Given this work has provided a baseline against which the cost and effort of implementing such future risk mitigation strategies may be judged, perhaps now is the time to change this attitude and develop suitable planning polices to help identify potential areas of vulnerability and support better long-term management and resource allocation in case the risk of another pandemic eventuates.

5. Acknowledgements

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Challenges and opportunities emerging in the recovery of the aviation sector from the COVID-19 pandemic

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Abstract This exploratory study sought to examine the impacts of COVID-19 and emerging challenges and opportunities from aviation recovery. Using archival and secondary data analysis, the study found that there are several challenges to aviation recovery. Chief among them are labour challenges and extreme weather events, which have been responsible for traffic disruptions in major aviation markets such as Europe and the USA. Other emerging challenges include high debt, inflation, interest rates, fuel, cost of labour, and general operational costs. The study recommends several interventions to deal with the challenges faced by the sector, including adopting risk disaster preparedness and management as a way to foster sustainability.

Key Words *Labour Challenges, Climate Change, Ukraine War, High Fuel Costs, Sustainability.*

1. Introduction

COVID-19 had a devastating impact on the travel and tourism industry across the world. Various destinations, sectors, and subsectors of the travel and tourism industry were adversely affected by the pandemic with a varying magnitude (Škare et al., 2021). At the pandemic's peak, various governments and states responded differently to the pandemic to ensure survival (Meng et al., 2021). Even though the initial shock of the pandemic could have been uniform across various economies due to the hard lockdown approach adopted by various countries the situation evolved as time passed. (Ali et al., 2022). Post the initial shock, the experiences of living with COVID-19, in many respects, have been unique for each country and region, given differing vulnerabilities and resilience.

Besides affecting the economies, the COVID-19 pandemic also altered tourists' travel patterns and behaviours (Bhaduri et al., 2020; De Haas & Hamersma, 2020). This further complicated situations for many tourism enterprises globally. COVID-19, apart from triggering a wave of lockdowns, also triggered a phobia of travel amongst regular travellers (Dube, 2022). Many vulnerable population groups were discouraged to travel particularly long distances (Gursoy et al., 2021). According to Bin et al. (2021), COVID-19 also triggered a culture of virtual participation and meetings, which adversely affected the travel industry. Virtual events ballooned and grew during the peak pandemic, primarily driven by the internet. This inadvertently has long-lasting implications for travel trends, most in an adverse manner. Almlöf et al. (2021) argued that, in the main, the pandemic forced many people to abandon public transport usage in a bid to avoid crowded places due to the fear of infection. In other settings, the pandemic promoted greater usage of alternative transport, such as private vehicles and bicycles (van der Drift et al., 2022). There is no doubt that this adversely affected public transport service providers.

The advent of COVID-19 vaccinations offered hope for many travellers as it boosted travel intentions in many countries worldwide (Williams et al., 2022). The advent of the vaccine in late 2020 and early 2021 and the rollout of COVID-19 health and safety protocols coincided with a decline in COVID-19 infections. This gave hope for a new start and recovery for several economic sectors, including the travel and tourism industry. According to Ekinci et al. (2022) and Gursoy et al. (2021), the global economic recovery hinges largely on attaining herd immunity. As the vaccine rollout ensued, it became clear that the recovery, if ever it were to happen, was going to be complex given the staggered approach to which most destinations opened and other effects of the pandemic. This hugely affected travel patterns, particularly in the aviation industry, which depends on well-connected networks globally.

The pandemic reshaped airlines' route networks and aircraft (Deveci et al., 2022), which woke up to a new reality or the so-called new normal. As feared and postulated in the early days of the pandemic, the disruption caused by COVID-19 brought new chaos and order, which aviation and other tourism companies had to grapple with. This study seeks to examine the impacts, recovery challenges and opportunities faced by the aviation industry as it grapples with coming out victorious from the impact of COVID-19. The study is critical as it traces the journey travelled and offers insights into the future trajectory of this critical economic driver.

2. Literature Review

The aviation industry plays a central role in the global economy (Grewe et al., 2021; Dube, 2021) as it acts as a trade, industry, and collaboration vehicle. The growth in tourism witnessed pre-COVID-19 was largely driven by the growth of the aviation industry and air connectivity (Gössling et al., 2013; Salesi et al., 2021). The aviation value chain has positive economic spin-offs on other facets of the economy. As such, a robust aviation industry is beneficial, by and large, to the economic prospects of a country or region (Alsumairi & Tsui, 2017). This makes the welfare and well-being of the aviation industry a global concern.

The COVID-19 pandemic had a debilitating impact on the global aviation industry in the main. The impact of COVID-19 by far surpassed previous experiences with other aviation shocks, such as the Severe Acute Respiratory Syndrome (SARS) (Abu-Rayash & Dincer, 2020). The pandemic resulted in declines in air mobility in many parts of the world for both civilian and military flights (ibid). According to Dube et al. (2021), the COVID-19 pandemic's impact on aviation has been much more pronounced, given that it disrupted the global supply chain. The disappearance of airlines also adversely impacted the collection of weather data in some regions of the world (Nhamo et al., 2020).

Despite the negatives of the COVID-19 pandemic in some respects, the pandemic resulted in some unintended consequences. There is new evidence that suggests that in as much as there are a number of airlines that went bankrupt as a result of the pandemic, there are new airlines that emerged as startups in the aviation industry. Sun et al. (2022) noted that the pandemic ushered in a whole new era of airline startups which came largely at the expense of old airlines that had a better risk appetite and were innovative in their operations. Several of the new startups seem to have been in Europe and Asia. These present policy challenges for the sector in many respects (ibid).

There is a need to acknowledge that the pandemic, apart from unleashing terror on the tourist market, also created a whole new business culture and ecosystem. It forced a rethink of the tourism and aviation business model as we know it and resulted in many questioning the sustainability of the aviation business model. At the height of the pandemic, many employees in the tourism and aviation industries were laid off through retrenchments (Sobieralski, 2020; Do et al., 2022). Many of the laid-off staff were skilled and experienced. Indeed other staff members succumbed to the disease, while others opted for other jobs altogether. Many academics warned that the post-pandemic tourism aviation industry was likely to be transformed (Hall et al., 2020) and, in many ways, a departure from the old traditional industry.

Given that COVID-19 altered many aspects of people's lives, including those working in aviation tourism, there is a huge demand to understand how aviation companies were fairing during recovery. There is also a need to understand some of the innovations, successes, and challenges of the new normal, which is technology driven. Such learnings are key for policy, practical interventions, and future pandemic lessons. It is against this background that this study is conceptualised. With the new normal after some severe cash burn, new challenges emerged, and so are the new opportunities that this study seeks to explore. The study emerges from the highly touted uncertainties that were highlighted post the emergency of the COVID-19 pandemic (Sun et al., 2022).

3. Research Design

The study makes use of archival data. The aviation industry produces a lot of data on a minute-to-minute basis as data is generated from online search engines, bookings, ticket sales and mobility activities. Therefore, there is ample data that can be analysed and used for policy and practice within tourism and aviation that is instantaneously produced daily. From an aviation perspective, the aircraft's landing, departure and movement produce adequate data that can be used to make a timely decision based on the availability of this data to the right user. This makes `it inexpensive for researchers to utilise this data in the industry and for academic studies.

This study utilises data from authoritative sources which collect this information from industry players such as airlines, air navigation companies and airports, amongst other such sources. Therefore, the aviation industry produces a lot of big data available for usage by various stakeholders. A full-blown primary data collection for this research would also be almost impossible given the sheer size of the study area and would not necessarily yield any different results than those presented here.

This study principally utilises data from archives and reports from Airlines for America, EUROCONTROL and International Air Transport Association (IATA). Airlines for America (A4A), previously Air Transport Association of America, Inc. (ATA), was founded in 1936. It is one of the oldest and biggest airline associations which represents airline passenger and cargo traffic in the USA. This organisation collects data for all the aviation players and acts as a one-stop shop for the bulk of aviation data for the USA and other international aviation data. On the other hand, EUROCONTROL is an aviation intergovernmental organisation comprising 41 Member States and two states with observer status. It provides air navigation services to military and commercial and civilians. The organisation manages the European ATM Network (with nearly ten million flights annually) in close liaison with the air navigation service providers, airspace users, the military and airports (EUROCONTROL, 2022). The study also used additional data sources from aviation blogs and international aviation data sources such as IATA, Flight Radar, FlightAware and other key aviation sources such as Notice to Airmen (NOTAM). These data sources account for a large portion of the global aviation industry and, as such, can be considered to be broad enough to offer insight into what is happening within the aviation industry. The bulk of the data that was analysed was for the period 2019 to August 2022.

Content and thematic analyses were the principal analytical tools used to analyse the data. The study used research questions and sub-research questions to acquire relevant data for this study. Additional analysis was done using Microsoft Excel Toolpak. Of interest was to explore the data that talks directly to impacts and challenges remedies adopted by the aviation industry in response to the impacts of the COVID-19 pandemic.

4. Results and Discussion

4.1. COVID-19 Impacts on aviation and implications

The study found that the pandemic's worst impact was felt in 2020, with recovery starting the same year in the second half of the year (Figure 1) and continuing in 2021 and 2022. Evidence shows that significant recovery progress has been witnessed, with the aviation industry edging closer to the levels that were witnessed in 2019, which act as a baseline for the aviation industry on which the impact of COVID-19 is based. The prolonged decline in volumes of traffic recovery teethers means that aircraft were parked and not making as much revenue. This adversely affected the aviation industry's value chain, adversely posing challenges for recovery. The long period of cash burns as aviation battled to recover resulted in some airlines, airport companies, businesses and employees of various aviation entities experiencing immense suffering. This is confirmed by previous studies, which state that the impact of COVID-19 on aviation was adverse across the value chain (Deveci et al., 2022; Ng et al., 2022; Su et al., 2022).

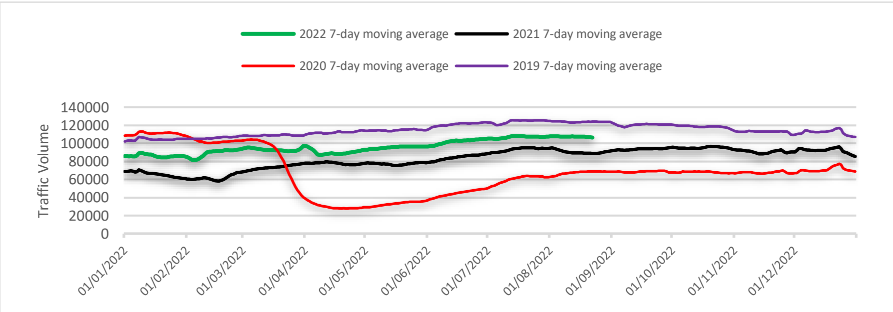

Figure 1: Global Traffic evolution impact and recovery from COVID-19. Source: Author Data from flightradar24.

The COVID-19 pandemic reset the aviation and tourism industry in many respects. These impacts varied across global regions, which created various challenges, some unique and some generic to the sector as a whole. The following sections look at the evolution of air traffic in some of the biggest global aviation markets.

In the American air market, evidence shows that significant recovery only started taking shape for the Atlantic and Canada in late November 2021. This means that the region had a much more prolonged cash burn. The cash burn was particularly even more pronounced in the Pacific as the recovery process has been slow (Figure 2). In Mexico, Latin and Domestic USA market recovery started in the second half of 2020. Nonetheless, the recovery has been punctuated by declines probably mirroring restrictions that various governments imposed to curtail the spread of the pandemic. On the other hand, the market tended to respond adversely to spikes in infections often characterised by the discovery of new COVID-19 variants which meant stricter control measures.

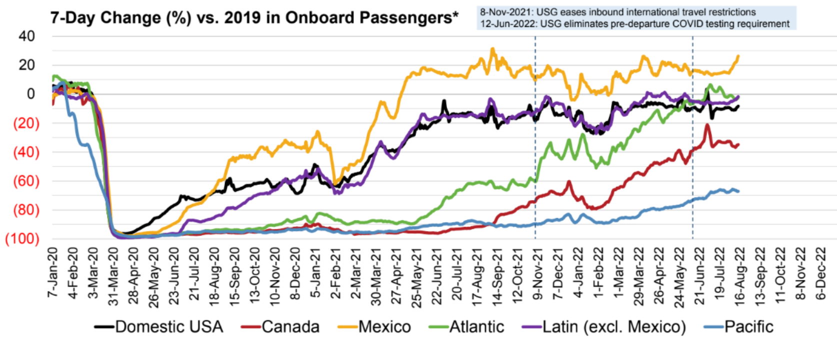

Figure 2: 7-Day Change (%) vs 2019 in Onboard Passengers. Source: Airlines for America, (2022:8).

In Mexico, however, the recovery surpassed the 2019 levels in the main, with passengers onboard airlines mainly in the positive territory. The domestic travel market has significantly recovered, with peaks in mid-year 2020, April 2021 and March 2022 after the Omicron variant's discovery in late 2021 and early 2022. There is evidence that the domestic USA tourism market has edged closer to 2019 levels showing evidence that there is some steady confidence in domestic travel.

This market development is not unique to the aviation industry, but other sectors have experienced the same trajectory where domestic tourism is the first to recover. This confirms the earlier anticipation that COVID-19 would trigger a different trajectory regarding tourism recovery. Woyo (2021) argued that in post-COVID-19, domestic travel offered one of the best options for tourism sustainability. The industry and uncertainty imposed by the pandemic also pushed several people into opting for more localised travel to avoid the complications of international travel amidst the raging pandemic. This kind of tourist behaviour has implications for the type of aircraft that airlines can use. Evidence from Flight Radar and FlightAware indicates that most airlines were opting for the deployment of their much more fuel-efficient and medium-sized aircraft.

In the European market, the cargo was not as severely adversely impacted by the pandemic as other segments of the sector. The overall picture shows that the sector benefitted from the pandemic as it witnessed growth in business despite the pandemic (Figure 3). Cargo operations remained largely in the positive territory throughout the pandemic. The other segments of aviation experienced the initial shock caused by the pandemic, which resulted in a steep decline in March 2020. Nonetheless, the recovery trajectory has been different across the various segments of the aviation sector. Business aviation recovery started in April, soon after the sharp decline in March 2020. In July 2020, the segment surpassed the 2019 figures, although it declined soon after that, peaking up into positive territories during the Christmas period in December and January in 2020 and 2021. As of June 2021, business aviation has been operating way above the preCOVID-19 levels. This demonstrates the resilience of that particular market. Business travel also offers more secure travel as it limits the interaction with the majority, like in the conventional airline industry addressing traveller fears and the demands for crowd avoidance for health safety reasons.

Figure 3: EUROCONTROL Market performance and COVID-19 recovery. Source: EUROCONTROL (2022:6).

Charter flights also seem to have witnessed better recovery, although there are signs that this sector was sensitive to variations of the pandemic probably because of the consequent travel restrictions, which limited mobility. Between October 2021 and March 2022, the sector was operating better than the pe-COVID-19 situation. The downward spiral seems to have been triggered by the Russia-Ukraine war, which started on 24 February 2022. The war triggered a global economic turmoil which resulted in global market pressure characterised by high inflation and fuel costs and subsequent interest rate hikes.

There has been generally a slow recovery regarding other aviation segments, including low-cost, mainline, and regional airlines. There is evidence of adverse impacts of different variants, including Omicron, which had a pushback effect on the recovery process in late 2021 and early 2022, although the general picture shows a general pattern of recovery in the trajectory of the sector, which points to improvements. As of 8 August 2022, low-cost airlines had recovered better and trailed behind the 2019 levels by -9%, while regional was -21% and mainlines trailed at -20%. The uptake in low-cost airlines could be attributed to more people utilising them, given the affordability challenges induced by COVID-19. Given the inflationary pressures associated with the COVID-19 recovery period, consumers were looking for cheaper deals to offset the financial squeeze. Mainline and regional airlines remained challenged by changes in travel behaviour, consumer confidence and restrictions, hampered the wholesale travel by tourists.

4.2. Travel recovery challenges

Aviation recovery came with many challenges, some of which were not anticipated at the onset of the pandemic and prior to the pandemic. One of the biggest challenges the aviation industry had to battle was the increased cost of doing business induced by the pandemic and other external factors directly and indirectly attributed to the pandemic. When the pandemic started, several airlines and aviation companies did not have adequate financial resources to fund operations during the international shutdown in March 2020. Airlines had to resort to other mechanisms to fund unavoidable cash burn. Some airlines were forced into adopting measures such as furloughing and retiring staff and older aircraft to manage better their cash reserves and debt associated with aviation operations at that time (Gössling, 2020; Nhamo, et al., 2020).

Disruptions in the aviation and tourism industry led many to question the sustainability of working in the tourism and aviation sector (Higgins-Desbiolles, 2020; Polukhina, et al., 2021). This resulted in people looking for jobs elsewhere. This deprived the industry of many experienced and knowledgeable individuals. On the other hand, employees working already in the industry that was dissatisfied with their salaries were forced by economic pressures to demand more and resorted to industrial action, such as industrial actions at airlines and airport staff in demand for better working conditions at the end of 2021 and in 2022. This resulted in disruptions to air traffic at airports and the global airline industry and the issuance of several NOTAMs on the same. The shortage of skilled personnel adversely affected airlines and airports in the USA and Europe. Heathrow Airport International, for example, was forced to put a cap on the number of travellers per day, limited to 100 000 per day (Heathrow Our Company, 2022). The capacity limitations were put in place from July 2022 and set to be in place until October 2022.

The capacity cap was placed to deal with staffing challenges as the passenger volumes grew faster than anticipated. This resulted in chaos at the airport, which resulted in luggage losses and delays and some luggage not travelling with their owners. Other challenges were long queues at check-ins and burgage collection for arriving customers. Other airports that placed capacity caps to deal with a huge influx of people moving to catch up with the backlog imposed by COVID-19 include Gatwick, Frankfurt and Schiphol in Europe (See Figure 4). In mid-August 2022, it was reported that there were about 21,000 flight delays and 1,600 cancellations (Forbes, 2022). In the USA, there were 20% flight departure delays at four airports, and the highest flight delay was 36% at Denver International Airport (Ibid). Such disruptions placed many inconveniences on the travelling public, with huge financial losses for all the tourism stakeholders.

Figure 4 shows that apart from staffing and capacity challenges, which have been growing since March 2022 to near levels seen in 2019, evidence also shows growing challenges of weather-associated disruptions at airports across Europe. EUROCONTROL blames most of the weather-related departures on Cumulonimbus (Cb). The heating of air close to the surface is one of the prerequisites for Cb formation. Europe has witnessed record-breaking temperatures between June and July 2022, with many stations recording record temperatures, some as high as 40°C. A study by Zachariah et al. (2022) observed that climate change made the temperatures in Europe in the year 2022 10 times more likely, and without climate change, temperatures observed in Europe would have been 2°less hot. The heat in Europe coincides with increased Cb weather disturbances (Figure 4). Climate change can, therefore, not be ruled out for causing weather-related disruptions to aviation in Europe during June and July of 2022. The persistent challenge of Cb is a challenge for aviation as it triggers air turbulence, can cause electrical challenges for aircraft and cause inflight icing. Given the harm caused by the same, pilots often resorted to rerouting in an avoidance tact, resulting in increased fuel burn and the associated costs.

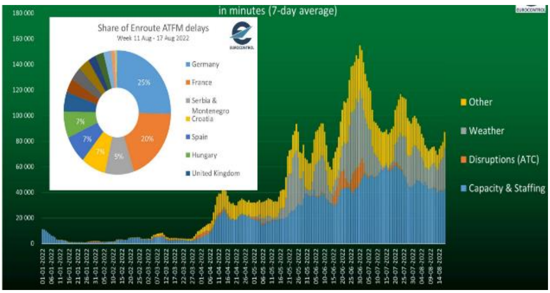

Figure 4: Enroute ATFM Delays in Europe. Source: EUROCONTROL (2022).

There is also an increase in flight delays from other reasons such as Air traffic control (ATC) and other disruptions. It is unclear whether these are related to labour or other COVID-19-related challenges.

In many respects, the recovery period came amid growing global inflationary pressures and high-interest rates (Figure 5), and raising the cost of living. In order to attract back employees and new skills, the aviation industry had to push up salaries and wages to make it attractive for personnel to work in the aviation industry. The struggling airlines had to battle high wages bills, which hampered the recovery process.

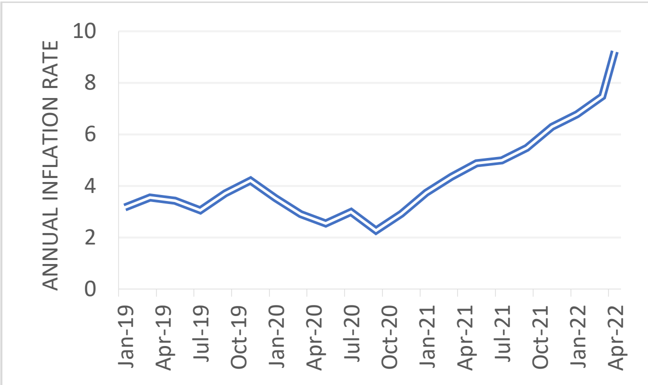

Figure 5: Global average inflation rate. Source: Authors Data from Statista.

The hyperinflation environment came with another challenge not seen during the height of the pandemic season. At the height of the pandemic, global oil prices tanked, providing some relief and allowing many airlines to remain afloat (Dube et al., 2021). Due to geopolitical factors, oil prices rose significantly in the first quarter of 2021, which offset the little reprieve that had taken root at the height of the COVID-19 pandemic. The tension and the ultimate outbreak of the Russia – Ukraine war and subsequent efforts to punish Russia by the Western countries and the USA further complicated the fuel prices and led to even more fuel price increases in early 2022 (Figure 6). This subsequently increased operational costs for airlines. This threatened the survival and sustainability of airlines, particularly those that did not have access to financing. The sharp increases in fuel came at a time when airlines were making frantic efforts to service debts accrued at the height of the pandemic.

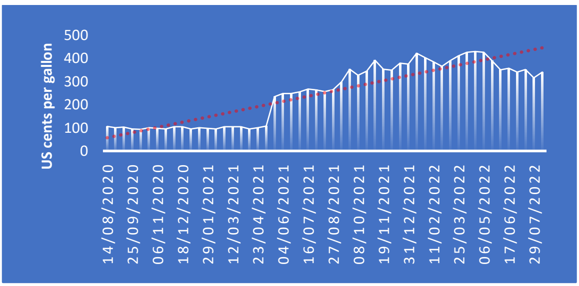

Figure 6: Fuel Price 2020 to August 2022.

In a bid to tame inflation, central banks across the world responded by increasing interest rates. This development had adverse impacts on debt repayment by aviation companies as it raised the level of debt by these companies. The increased interest rate is a challenge to consumers whose purchasing power has been equally eroded, which could adversely alter travel intentions. This will worsen the already suffering but recovering aviation sector, which is only expected to return to profitability in 2023 and led by America, which is set to record profits in 2022. According to IATA (2022), North America is set to witness profits of $8.8 billion in 2022. Other regions are expected to witness losses, with Europe expected to record losses of $3.9 billion, Asia-Pacific at $8.9 billion, Latin America at $3.2 billion, the Middle East at $4.7 billion, and Africa expected to witness losses of $0.7 billion.

4.3. Opportunities presented by COVID-19 in the aviation context

COVID-19 transformed several industries with many adverse impacts, which will take some time to rectify. Undoubtedly, these challenges came with opportunities that can advance industry aspirations. One of the accusations which have been levelled against the aviation industry was that it is carbon intensive and significantly contributes to climate change, and in many respects, unsustainable in many regards. The decline in aviation traffic came along with significant reductions in carbon emissions. In many respects, there is a need to ensure the recovery process is sustainable. There is evidence that as the recovery process occurs, some areas have significantly lower carbon emissions than in 2019 (Figure 7), which is the base year. IATA estimates that carbon emissions from global aviation will rise to 809 million tonnes, up from 905 in 2019 (IATA, 2022). The quest for NetZero is one of the global aspirations that every aviation manager is clamouring for to meet investor and client demands for sustainability within that sector.

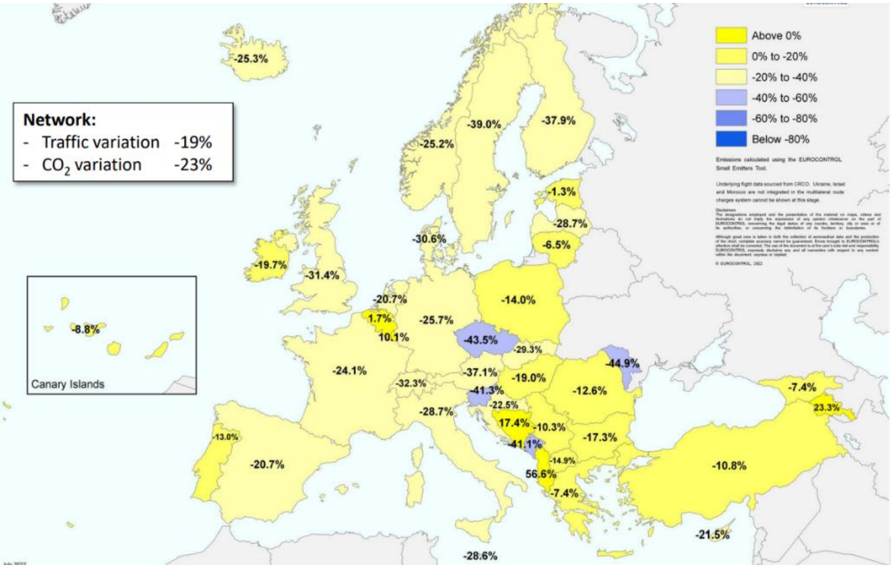

Figure 7: CO_2 variation from January to June 2022 Vs 2019 departures. Source EUROCONTROL (2022).

The industry can leverage some retired old aircraft to purchase and bring on newer, more fuel-efficient airlines. It is therefore, encouraging to note that of the aircraft that were delivered in 2021, the bulk of them was in the high fuel efficiency category. Airbus, for example, delivered 459 aircraft from its neo fleet range and 221A321ceo while Boeing delivered 245 of 737 MAX (flightradar24, 2022), which are considered some of the most fuel-efficient fleets on the market. This will help airlines to move towards NetZero.

Riding on the demand for sustainability consciousness that has been reignited by the COVID-19 pandemic (Severo et al., 2021), the aviation industry can use the momentum to lobby for greater environmental actions concerning cutting carbon emissions. Tourists can be encouraged to take initiatives such as offsetting their carbon emissions, mainly through market-based measures and purchasing carbon credits. Greater efforts can also be made to lobby tourists to as much as possible travel light with regard to travelling light as part of the new culture of travel that is environmentally sound. Such efforts can assist in reducing the environmental cost of the aviation sector.

There is a lot more than the aviation industry can do to leverage the current situation. The sector should use the time to invest in efficient route operations in preparation for the full sector's recovery. This will save airlines money and also assist in reducing flying's carbon footprint. Research and innovations in Sustainable Aviation Fuels can be ramped up with a view of ensuring that the costs for the same drastically come down to near prices of jet fuel or avgas as current prices are prohibitive. Rolling out distribution infrastructure for the same will assist a great deal in nudging the sector towards sustainability.

The COVID-19 pandemic also ushered in the heavy deployment of technology within the aviation sector (Serrano & Kazda, 2020). The industry can continue to progress and promote smart travel at an increased pace which can assist in better travel and ensure the sector is well prepared for future pandemic events. Various advantages also have been witnessed through the COVID-19-induced technology system, which increases security and assists aviation in moving towards a paperless sector. Moving away from paper can also assist the industry in reducing its carbon footprint.

5. Conclusion

The study sought to assess the challenges and opportunities faced by the aviation industry as it seeks to recover from the COVID-19 impacts. The study found that the impact and recovery of COVID-19 have not been uniform across the world, and in some destinations, the recovery was slow owing to various factors amongst differentiated control measures aimed at containing the spread of the COVID-19 pandemic. Global challenges are facing the aviation industry as it seeks to recover. Chief amongst them is geo-global-political and economic factors, such as increased interest rates, inflation, the rising cost of fuels, labour challenges and the Russia-Ukraine war, among other factors. These factors, including climate change, complicated the recovery process, threatened to slow the recovery process, and could throw some aviation players out of business as continued disruption of the sector threatens its short-term viability in some geographic regions.

The study identified several areas where the aviation industry could take advantage of the situation of COVID-19 when it disrupted the sector. Amongst some of these areas is the need for the sector to increase the pace of technological innovation, and there are opportunities to address climate change and other sustainability issues. Given lessons learnt from the pandemic, there is a need to deal with increasing the financial buffer reserves to allow the sector to respond to future disasters and the pandemic. The aviation industry needs to think and put better safety nets to improve resilience in existential threats such as pandemics and other natural disasters.

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Digital Technologies and Passenger Experience at Airports: a scoping review

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Abstract Airports have witnessed digitalization in response to the emergence of technologies over the last decade, this coupled with the COVID-19 pandemic has exacerbated the need for airports to adopt cutting-edge solutions such as contactless technologies and robotics to facilitate travel in the upcoming years. The sharp rise in travellers returning to airports, has led them to work towards enhancing the experiences of their customers by implementing new technologies. This paper summarizes the existing literature on the digital technologies employed at airports and how they influence passenger experience. This paper will contribute to knowledge about technologies that positively affect passenger experience and can help airports take advantage of these technologies by increasing adoption at airports around the globe.

Key Words *Airport Technology, Innovation, Passenger Experience, Self-Service Technology, Biometrics.*

1. Introduction

Travellers with higher expectations are placing tremendous pressure on the aviation industry as air traffic continues to grow. While airlines feel the squeeze, airports also need to respond to these changing conditions if they want to remain competitive. The continually changing needs of passengers (Chambers, 2007), who are accustomed to seamless, quickly evolving technological surroundings at home and at work, in addition to passengers becoming increasingly aware of the stress involved in travel have resulted in the need for better passenger experiences. The airport experience can be distressing and frustrating for passengers who may feel they are being juggled from one touch-point to another (Halpern & Graham 2013; Graham 2018). Prolonged flight delays, cancellations, security screenings, misplaced baggage and other events have intensified the airport industry's turbulence. Research has shown that the average processing time has doubled from what it was pre-COVID-19 (IATA, 2021). These long waiting times with airports only processing half the number of passengers compared to in 2019 – have proven to be stressful for passengers. Airports are falling short of providing exceptional customer service and meaningfully segmenting their client base. Thus, an insight into how advanced technologies can help the industry reverse the tense situation caused by the Covid pandemic and improve experience and satisfaction for passengers.

According to numerous academics, the thrill of flying has been conquered by unpleasant and stressful encounters as a result of crowded airports, increased travellers, and nerve-racking security checks (Meuter et al. 2000; Saeid and Macanovic 2017; Wang et al. 2012). According to a study by Yang et al. (2015), broadly speaking, the majority of airports fail to respond to travellers' expectations. The passenger experience on the ground is increasingly being shaped by technological developments (Tan & Masood 2021). Airports have been on the digitization journey for a while; however, they are now accelerating it to become more digital than ever before (Fattah et al. 2009). Passenger experience is the priority for airports when making investment decisions, and technological solutions are being acknowledged for the value they have in improving the passenger experience (Brida et al. 2016).

Although there is a fair number of studies on the impacts of deploying digital technologies on airports terminals from the passenger's perspective, however, it has not been systematically summarized. This makes it challenging to identify which technologies have been widely studied and are particularly promising with respect to passenger experience. Thus, the goal of our paper is to address this gap. This paper explores what is known from the existing literature regarding passenger's experiences with new airport technologies. Although some studies have reported a negative impact of technologies on the airport, largely research finds that employing technologies has a positive effect on passenger experience. This study contributes to the field of academia and industry by identifying the impacts of new technology implementation under the key area of passenger satisfaction. Airlines can benefit from this review by studying the impact technologies have on customers prior to selecting specific technologies to implement. The paper concludes by highlighting future research priorities on implementing the concept.

2. Methodology

A scoping review of the academic literature on passenger experience related to technologies adopted on the airport was conducted using the Six-Stage Methodological Framework for Scoping Reviews, outlined by Arksey & O'Malley (2005). The goal was to map the existing research on this topic and identify knowledge gaps, without making any prior assumptions about the literature's scope, range, and key findings (Peterson et al. 2016). This paper aimed to gather academic data on innovation at airports by reviewing studies published from 2015 to 2022 for presenting key findings.

For the initial step, to define the research question informed by the guidelines of the Six-Stage Methodological Framework, a broad research question was developed for the literature search, asking: what does the academic literature from 2015 to 2022 inform us about the impact of digital technologies on the passenger experience at airports. Over the past year, a significant amount of innovation has been fast-tracked within the airport sector, but to make informed investment decisions, it is essential to understand their impact. The focus of inquiry was thus narrowed down to three areas: Firstly, the types of technologies commonly discussed in the literature; Secondly, how these technologies are affecting passenger experience and finally, the key benefits of these technologies to passengers at airport terminals. In order to transform these questions into searchable queries consistent with research database requirements, the keywords were used "airport technology impact on passenger experience", "smart airport effectiveness", "airport digital transformation", and "future airport technological innovation", "customer satisfaction" and "airport new technologies and user experience".

In the second stage, all relevant studies were identified on databases such as ScienceDirect, ProQuest Central, Academic Search Premier, SCOPUS, Emerald Insight, and EBSCO. The review included empirical papers published between 2015 and 2022. A systematic search of all relevant online research databases, as well as snowball search methods and reference tracking were conducted in order to identify additional articles. The reference sections of the papers that came up in the original search were also screened to ensure that relevant literature was not overlooked. Terms used for the literature search - airport OR airport operation OR airport terminal OR smart airport AND passenger experience OR customer satisfaction AND new technologies OR technological innovation OR innovative technologies. For the third phase of study selection, publications were screened based on titles and abstracts for inclusion in the study. During initial abstract screening, 84 potential studies from 113 were selected in the first round of abstract screening. Full text article reviews in the second round of screening resulted in a total of 60 articles and grey literature which were included in the review.

In the fourth stage of the review, the data was charted, by creating a literature extraction tool in Microsoft Excel to record the author, date of publication, location of study, study outcomes,.

number of participants, research methodology and topic. The fifth stage of the review, known as the collating, summarizing, and reporting phase involved analysing the data, reporting the results, and applying meaning to these results. To efficiently and effectively conduct the analysis, the data corresponding to each study included in the review was examined. The material was then analysed to identify key themes and/or commonalities and differences between and across studies. The themes inductively derived from the data included: the technologies being adopted at airports, the positive or negative impact of these technologies on passenger experience, effects of these technologies on passenger experience. The papers were coded based on their relevance to major theme. Upon analysis, gaps were identified in the literature.

The sixth stage of the review, known as the consultation stage with stakeholders is an optional stage. This stage looks at incorporating expert consultation and feedback into the process, which was not needed for this review.

3. Key Findings

3.1. Characteristics of included literature

Analysis revealed that the publications appear to follow a trend of increase over the course of the last decade reflecting a growing adoption of technologies by airports as well as an escalating interest in the impact that these smart technologies have on the passenger experience. Over half of the literature was published from 2015 to 2022. The highest number of studies were conducted in 2016. Twenty-six studies reported qualitative data, while 15 reported quantitative data and 2 reported mixed data. The most common study design was surveys and questionnaires. A majority of the papers focused on self-service technologies, followed by papers on biometric-enabled technology. Furthermore, the vast majority of papers focused on major international airports in the USA, Malaysia, Qatar, UAE, Kuwait, Thailand and China.

3.2. Digital Technology and Passenger Experience

Recent studies have looked at how overall digital technologies have affected passengers' experiences. According to findings, new technologies can assist airport managers in raising and improving traveller happiness and fostering a great experience because it is crucial for any airport (Yaqoobi, 2019). In a survey of 94 airports, Halpern et al. (2021) investigated the use of technologies that result in a more seamless and personalised experience at airports and reported that they improve passenger experience. They observed that standing in queues repeatedly at airports had a significant negative influence on travellers' experiences and was linked to elevated stress. Information technology was also discovered to be a significant stimulant for the airport experience. Airports were able to improve the customer experience and reduce frustration attributable to information technology and digital transformation (Jiang & Zhang, 2016). Additionally, it was seen that new technologies improved the efficiency and precision of luggage handling, particularly during dual flight transfers. When the status of baggage delivery can be easily tracked, passengers stand better informed. All of these features help passengers feel more at ease, which raises their satisfaction and enhances their experience with the airline (Mishra, 2010). Technology adoption has provided the opportunity for airports to plan the passenger experience so that they have control over what to anticipate while still processing people in a way that affords them control. Abolina (2022) conducted a survey at the Riga International Airport which made it apparent that innovations not only enhanced operational efficiency and security, but they also made the airport experience quicker and comfortable for passengers. Although digitalization, automation and touchless airport solutions are shaping the future of the airport, human resources still have a crucial role, particularly in terms of providing friendly service and ensuring passengers were enjoying the experience.

Exceptional flexibility in passenger processing, communication, and tracking has been made possible by new technologies in the airport, such as Radio frequency Identification (RFID), mobile self-service apps, and wireless one-on-one communication, that have a favourable impact on passenger experience (Wattanacharoensil et al. 2016). Based on the analysis, there is no uncertainty that, if well-conceived, digitalization will have a significant impact on travellers' airport experiences (Nordqvist, 2022). In their study of a few rural airports in the Czech and Slovak Republic, Plško and Remencová (2022) concluded that digital transformation is the optimal approach for boosting operational effectiveness, minimizing operational expenses, and boosting passenger satisfaction. The SITA Passenger IT Insights 2019 survey makes clear that the arrival of new technologies had a positive impact on passenger satisfaction. Technology enables travellers to experience pleasant emotions on their journeys. A case study using a simulation model to assess the impact of forthcoming changes on the airport's departure hall was developed at Lisbon Portela airport. Data showed that, as a result of the implementation of passenger facilitation systems, process times at the check-in and security checkpoints dramatically decreased (Kalakou, et al. 2015). Another case study at the Dubai International Airport conducted by El Najjar (2018) utilising questionnaires revealed that the use of technology advances to deliver services increased customer satisfaction and positively influenced travellers' behaviour toward the airport. To enhance the passenger experience, many airports are making investments in digital technologies including smartphone applications, self-service check-in, luggage drop, and wayfinding maps (Straker & Wrigley 2018). Aviation technology is revolving around eight key technologies: biometrics, self-service and automation, artificial intelligence (AI), blockchain, cybersecurity, onboard connectivity, robotic assistants, and smart ground transportation (Cui & Lee 2015).

3.3. Self-service Technologies

The most commonly examined technology was self-service technology. The literature revealed that there is a particular emphasis being placed on self-service technologies. In most studies, self-service technologies have a favourable impact on the passenger experience. Airports are rapidly deploying self-service technologies (SSTs) as a strategy to improve passenger experience by eliminating operational inefficiencies (Zai & Ghadzali 2021; Shin & Perdue 2019). The key benefits of an integrated passenger self-services programme are greatly enhancing the overall passenger experience and improving the passenger flow (Barich et al. 2015). In a study by Bogicevic et al. (2017), they surveyed 174 university alumni and 189 US residents and found a positive relationship between airport self-service technologies and passenger confidence benefits and enjoyment, which results in positive effects on travellers' overall satisfaction. With technologies such as these a passenger, having checked in at the self-service kiosk and dropping his baggage at the self-service bag drop points, can immediately go to passport control and boarding, thus reducing queues and allowing people to pass through all airport formalities before flight during 10 minutes (Gualandi et al. 2018). Otieno & Govender (2016) and Seetanah et al. (2018) in their research established that the use of self-service kiosks allows the processing of a significant number of passengers to be de-centralised from the airport itself. From the customer's point of view, this can speed up the time-consuming service and offer flexibility to the customer as they can access the technology conveniently. Over 87% of passengers are pleased with the self-check-in process, owing to its quick response time of around 50% of the regular transaction time (Cui & Li 2015).

According to Boudreau et al. (2016), the installation of SST kiosks can assist airports in improving customer experiences by enhancing airport efficiency as it shortens wait times and accelerates procedures. Self-service and contactless technologies for every procedure at the airport have been found by Serrano and Kazda (2020) in an explanatory study to reduce operational costs, enhance passenger satisfaction, and minimise virus spread. Findings from a study by Taufik & Hanafiah (2019) on travellers who used the self-check-in kiosks at Kuala Lumpur International

Airport, found them to be more at ease with SST and found that the necessity for human interaction was immaterial to the traveller's airport experience and satisfaction. Zai and Ghadzali (2021) found that most passengers preferred the self-service check-in system at Kuala Lumpur International Airport 2 because it reduced queues and provided passengers with better privacy while checking in. This also proved to be convenient for the passengers as the kiosk's location was in near proximity to the airport entrance. But they discovered the system to be challenging for the older generation of passengers to use. There is some literature which suggests that not all consumers are amenable to SST; some consumers appreciate more conventional forms of human engagement (Bogicevic et al. 2017; Considine & Cormican 2016). A Passenger Satisfaction Survey (2016) conducted at the at C.S.I Airport, Mumbai seconded academicians who claim that the addition of technology such as self-service check-in, and self-service security have led to some amount of de-personalization in passenger experience.

In their study of 20,000 passengers at five Spanish airports, Castillo-Manzano and López-Valpuesta (2013) found that self-service technologies gave travellers a sense of empowerment and independence. According to the Transportation Research Board of the National Academies (2008), the aviation industry views SST as the "Holy Grail" for enhancing the passenger experience. In response to changes in customer behaviour and lifestyle, some airlines, including Thai Vietjet, Thai Smile Airways, and Thai Airways, have implemented SSTs (Nok Air 2020; Thai Airways 2019). However, not all customers are willing adopters of SSTs. SST also helped passengers save time and money because of the faster and easier interactions (Chen & Wang 2016). More than 25 airports were surveyed by Nau and Benoit (2017: 22–27), who discovered that SST advantages travellers. The global passenger survey by the IATA (2021) illustrated that SST tends to be embraced by passengers.

Otieno and Govender (2016) carried out a survey of 318 passengers during peak hours at the international departure terminals and found that SSTs addressed the lengthy lines at the airport and enhanced the customer service experience. Based on the aforementioned, it is argued that self-service technologies (SSTs) can give a positive customer experience and customer satisfaction merely by putting the passengers in charge of their own journey. In a similar vein, using a simulation, Patel (2018) showed how the introduction of a single token ID with SST improved operational process efficiency while ensuring safety and security thus improved passenger experience. In order to analyse novel services like self-check-in kiosks, Chen et al. (2015) collected data using online surveys and questionnaires over the course of two months. The results showed that these services have a positive impact on consumer satisfaction. The majority of respondents (93%) said they would continue using SST in the future. One airline has reportedly gone as far as testing a new contactless self-service technology to conduct contactless health inspections and automate current touch-screen systems, according to Future Travel Experience (2020).

The Copenhagen Airport has evolved into one of the few airports that provides the most self-service offerings, utilising technologies that result in shorter lines for baggage reclaim and quicker boarding times (Lufthavne 2016). The New Hamad International Airport in Qatar has 12 different self-service baggage drop locations with a single biometric system as well as 5 cutting-edge self-check-in kiosks to optimise passengers' time. This has enabled passengers to flow through the terminal without disruptions. They projected that the processing of passengers will ultimately be up to 40% faster, substantially upgrading the customer experience (future travel experience 2018). Al Kheder (2021) employed questionnaires to assess the level of customer satisfaction at the Kuwait International Airport, which had a congestion issue that significantly reduced its performance. Self-check-in kiosks were evidenced to be an effective tool for managing extra travellers while also improving the overall traveller experience in the airport.

3.4. Biometric Technologies

Another technology with a few mentions was biometrics. From the review, it emerged that since the U.S. Department of Homeland Security has approved facial recognition technology as the specific biometric method for passenger identification and verification during entry and exit procedures into the U.S., the use of biometric technologies at airports has vastly increased (Khan & Efthymiou 2021). Furthermore, they found that the use of multimodal biometrics can lead to increased efficiency inflow and a better experience for the traveller in a case study of Biometrics at Dublin airport. According to Kalakou et al. (2015), the traveller experience is evolving and growing owing to cellphones, Big Data, biometric systems, and near-field communication. In 760 passenger interviews conducted at three distinct Brazilian airports in 2019, Negri et al. found that 82.94% of respondents favoured using biometric check-in technology.

Literature has provided evidence that technology inside airport terminals that influence satisfaction, service quality, and thus experience include, biometric security technology (Rajapaksha & Jayasuriya 2020), self-service check-in (Sabatová et al. 2016), mobile touchpoints and solutions (Inversini 2017; Rossi et al. 2018). An examination into the usage of biometric technology at Beijing Capital Airport found that an application dubbed "Smart Path" was placed at several checkpoints for manual check-in, self-service check-in, luggage drop-off, and even boarding. This improved efficiency means shorter queuing time and more social distancing for passengers. Additionally, due to it being contactless, the chances of contracting COVID-19 infection decreased (Biometric Technology Today 2020). As more than 400 passengers can board an aircraft in less than 20 minutes, the technology has proven to be lucrative. Numerous airports in the United States and other countries have now fully adopted biometric entry and exit schemes, according to the report. Mineta San Jose International Airport became the first on the U.S. West Coast to use facial recognition to identify every international passenger in 2018, enhancing not only security but also the travelling experience (Burt 2018). Due to the implementation of biometric entry and exit screening, waiting times at Orlando International Airport were reduced by about 4 minutes (Burt 2018).

According to SITA's (2019) research, technology and automation increase travellers' feelings of satisfaction. SITA (2022) has seen a growing appetite for mobile and self-service options, which are directly linked to higher passenger satisfaction levels. It was revealed that users of biometric gates reported a 5% higher level of satisfaction than those who dealt with human agents. Passengers' concerns about privacy and security were one of the main biometrics-related issues raised in the literature. Despite this, surveys indicate that travellers are open to the use of biometrics at airports, with more than 90% of respondents saying they would do so if it were an option. Findings also demonstrate that when using biometrics led to appreciable enhancements in passengers' experiences travelling through airports, passengers were willing to trade some of their privacy rights and support its use (Abdulwahid et al. 2015).

3.5. Radio Frequency Identification, Near Field Communication and Emerging Technologies

The effects of Radio Frequency Identification (RFID), Near Field Communication (NFC), and other emerging technologies have been examined by a small number of studies. RFID was observed to lower luggage mishandling rates by 25%, which results in massive savings for airlines and, more importantly, improves the travel experience for passengers (IATA, 2016). SITA (2017), TechTarget Network (2016), Beaconstac (2016), Future Travel Experience (2016a, 2016b, 2017a, 2017b) and Royal Aeronautical Society (2017), studied on RFID and found that it improved airport baggage tracking and security gate processing efficiency. One study that looked at the effects of NFC discovered that several airports are adopting it to make it easier for passengers to board at the gate or enjoy airline lounges. As per SITA (2017), NFC technology can help increase the sharing of mobile boarding passes from between 2% and 3% in 2011 to between 50% and 80% by 2018.

Amoah (2021) explored innovations in air travel that might serve as preventative measures against the spread of COVID-19. In order to reduce the number of places that travellers must touch, he observed an acceleration in the adoption of contactless technologies at airports. Several airports have implemented i-Beacon to improve the shopping experience, improve airport navigation, and guarantee that passengers get real-time flight information. Smart wearables are anticipated to play a significant part in the passenger experience (FlightView 2015). Overall, analysis found that biometric systems, near field communication, and big data can alter the traveller experience.

4. Discussion

The results of this review suggest that the implementation of new technologies as part of smart airports is gathering strength within the airport environment and shall continue to be relevant in the digital transformation journeys in developing future airports. The review made it evident that airports have been constantly evolving and adopting digital technologies to improve operational efficiency and enhance the passenger experience. Building upon existing reviews, this overview of 60 relevant articles aims to assess the available literature and explore the gaps in the current knowledge on the impact of utilizing new technologies at airports on passengers' experiences, both positive and negative were analysed in order to provide a holistic picture of these technologies and increase the understanding of how airport systems can be made more agile, flexible, enjoyable and resilient.

A majority of the studies showed that digital technologies implemented at airports enhanced passenger experiences. However, some issues like security concerns and the need for human engagement, have to be worked on to satisfy passengers' requirements. Airports must also consider the needs of passengers who are unfamiliar with, or uncomfortable using digital technology, even as most passengers are adopting technology. Moreover, many nations have an ageing population that may need assistance with automation and self-service technologies (Graham et al.2019). It is important that the preferences and needs of these passengers are not overlooked. Since there remains a small yet consequential section of passengers hesitant to adopt digital technologies as part of their journey, there may be value for some airports, especially those catering to particular passenger segments, to equip a traditional and human-to-human approach for passenger experience. Based on the analysis and results of this examination, the airport industry can develop a more effective digital strategy to improve passenger experiences and satisfaction. By segmenting passengers according to their preferences, airlines can account for variations in customer preferences and make investments and customer service decisions that are more accurate and focused.

Conclusively, the review found that new technologies have a positive impact on passenger experience on the airport terminals. By enabling and encouraging advanced technologies, airports are inviting customers to get involved in speeding up and simplifying their journeys. While validating the role of technology in passenger experience was the primary driver of this research, it was noticed that research in this area is: (i) mainly focused on self-service technology and biometrics, and (ii) predominantly concerned with the operational efficiencies achieved from the adoption of these technologies. Furthermore, most of the papers were published recently, indicating a rising trend in innovation at airports. It appears, however, that there is a paucity of published in-depth, systematic analyses that examine airport ground operations; although it might have relevance for an improved customer experience. As Smart Airport is still a developing concept, there is a paucity of peer-reviewed literature available on specific scopes under the smart airport operations and lack of general discussions on advantages, methods of practical implementation and challenges with special attention on terminal operations. Even though a reasonable amount of literature on the digitalisation of airports with a focus on enhancing passengers' airport experience exists, it is a rather scientifically unexplored territory. There are more scientific studies available regarding digitalising airports with a focus on improving operational efficiencies.

5. Conclusion

The purpose of this paper was to research the impact of airport technologies on the passenger experience through a review of the literature. The scoping review has shown that new technologies and passenger experience represent a rapidly growing area of research; however, it is underdeveloped and will need to accelerate and broaden in scope to include other technologies such as NFC and RFID. The review showed that digitizing airports significantly improves passenger experience, by improving check-in, baggage drop, immigration, security, boarding for departure activities passenger handling services and overall airport operation. These technologies help airport operators improve the passenger experience by providing touchless self-service processes with no wait time, timely event notifications on-demand contextual information delivery with baggage tracking, self-service for baggage drop and aircraft boarding, and biometric self-boarding gates. Considering the post COVID-19 scenario, airport managers can use his review to organise resources to ensure that airports can respond to changing passenger needs. The airline industry must embrace digital technologies as they continue to develop and change in order to provide high-quality passenger experiences. Considering the impact that digital technologies have on the industry, airports should adopt them in other aspects of customer service and touchpoints as well.

However, a limitation was that the literature had a strong focus on the operational efficiencies gained from the adoption of digital technologies in airports, but very limited studies have investigated the impacts on passenger experience from a customer-centric view. Moreover, the existing literature is mostly focused on self-service technologies and biometric technologies while very fewer have studied RFID-enabled tags, NFC and up-and-coming technologies such as Artificial Intelligence. Despite the limitations, the existing evidence points to a positive impact of new technologies on passenger experience. Moreover, future research can focus on the impact of new technologies on different customer segments, such as differences in experience across age groups. More research is also needed to examine a broader variety of technologies such as RFID and Near Field Communication being adopted at airports and their impact on overall passenger experience. The review is helpful to academics and practitioners to verify how these innovations have shaped the industry worldwide, making it more efficient, sustainable and safe.

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The Impact of COVID-19 on Decision Making for Long Haul Crews

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Abstract The purpose of this study was to understand how the COVID-19 environment, and its associated regulation impacted the decision-making of crews undertaking international flights over six hours, and whether national approaches to airspace influenced potential outcomes in the event of non-normal in-flight situations. Interviews were conducted with long-haul captains to understand their approach and methodology to the changing environment. A review of an airline's safety reports was also undertaken to compare 2019 with 2020 and 2021. Results demonstrated decision-making did adapt to ensure an equivalent level of safety during COVID-19 operations, resulting in modifications to standard operating procedures and in-flight strategy.

Key Words *Decision Making, Biases, Heuristics, Teamwork.*

1. Introduction

This paper aims to critically evaluate how the complexities and threats associated with governments' actions in managing the COVID-19 pandemic have impacted the action-based decision-making of long-haul airline crews whilst undertaking operational duties. Given that COVID-19 has been a single dominating factor in the last two years it will be an objective of the research to compare pre and post COVID-19 behaviours to assess if there has been a change in the choice of action the pilot would undertake in an otherwise identical scenario (Moss and Sandbakken, 2021). This will help understand if there was a predisposition for a particular decision outcome due to COVID-19-related information held as an opinion or bias by the pilot.

1.1. Objectives

The objectives of this study were to critically evaluate the underlying factors that influence pilot decision-making when operating globally during a pandemic through primary research using interviews, critically analyse whether pilot decision-making has changed from pre COVID-19 operations by assessing safety reports, assess whether COVID-19 induced operational and regulatory requirements have had an impact on attitudes or assumptions when managing non-normal in-flight operations, and how this impacted strategy decisions by the crew and finally make recommendations for organisations and future research.

1.2. Justification

The main value of this research was to be able to critically analyse the difference between pilot decision-making strategies pre and post COVID-19 and identify what aspects of the environment influenced any change of strategy or plan. The data derived from this could be applied to different scenarios to understand what influences action-based outcomes. It will be useful to examine if preconceived "realities" or opinions unduly influenced an approach to a specific problem. If it can be determined that crews do not approach a problem with a "clean sheet" mindset and demonstrate a predisposition to a certain course of action due to bias or schema, it could be integrated into a learned defence strategy to recognise this potential weakness. A pilot flying from Hong Kong to

London may divert to Beijing with a serious technical issue even if they believe they will probably be quarantined for several days (UK Gov, 2022). A pilot on the same route may deliberate in the event of a less serious problem that could allow continued operations, particularly with the knowledge that the next overflight country en-route had a more benign attitude to visiting crew.

2. Methodology

To understand how the COVID-19 pandemic has affected the decision-making of airline crews undertaking long-haul operations, it was necessary to consider their working environment and constraints that impact observation and analysis. Working in a safety-critical and highly regulated industry creates problems with access and interaction with the individuals who are the subject of the research project. The context of this research is set against the only available channels whereby information can be exchanged in a suitable environment (Richardson, 1996). All pilot interviewees had significant aviation experience with long haul command time ranging between seven and twenty-one years and were employed by UK based cargo and passenger airlines.

Also, important to note during the fight against the COVID-19 pandemic was a significant reduction in the UK flying program, the main activity being cargo supplies, and the priority was medical equipment and testing equipment with the most significant routes being to the USA or Far East, China, Hong Kong (WCO, 2022). Due to a reduction in international passenger travel of up to 70% (ICAO, 2022), there was a commensurate reduction in the number of UK crews actively working. Additionally, many crews did not have east and westbound exposure due to company flying programs and trip allocation, which impacted the available sample size for the study (Braun and Clarke, 2013). It was necessary to understand the background information that pilots considered important before making a strategic decision, it was assumed that a standard operating procedure reaction to events such as engine fire or emergency depressurisation would be handled similarly to pre-COVID-19 operations. The purpose of the research was to understand if pilots were influenced when dealing with emergencies or abnormalities that required a level of adaptive thinking or multi-option responses.

2.1. Research Approach

A qualitative approach was used for the primary research aim, utilising interviews to gain in-depth insight into specific concepts, allowing the pilots to describe and contextualise their thought processes (Banister et al.1994). The study aimed to understand if there was a recognisable framework pilots use to make action-based decisions in a dynamic environment, utilising their experience and knowledge to create an acceptable outcome. If a framework was evident, it would be helpful to know what impact COVID-19 had on the reference points, to understand if it was part of a schema as a structural consideration or exist as a bias that influenced general behaviour.

Having the interviews as primary research, with Occurrence Reports (OR) as a secondary tool, it was envisaged that the intentions and processes considered during discussion would have a material output reinforced by the safety data (Flick, 2018). The questions were open, and based on the following:

- Impact of new rules and regulations since COVID-19
- The operational impact of COVID-19
- Risk profiles
- Mitigations
- Specific challenges (minimum equipment list/ specific countries)

In addition to the interviews, access was granted to the safety team at a leading long-haul airline. The OR data was accessed and analysed under the supervision of a company representative. OR's can be filed by any member of the crew undertaking a flying duty, under Civil Aviation Authority (CAA) regulation it is mandatory to file a report under certain circumstances, for example, a level bust when an aircraft does not comply with an altitude instruction from air traffic control (CAA, 2022). There is also a discretionary element in self-reporting where the crew voluntarily surrender information concerning an error or oversight, and this includes commentary on other factors that they believe have a flight safety implications.

2.2. Methods of analysis

It is important to state that the data analysis was approached from a deductive perspective, utilising its content to evaluate hypotheses from naturalistic decision-making (NDM) theory. The analysis focused on taking more generalised discussion and creating themes and specific sub-themes to evaluate the output (Blaikie, 1993). Using Blaikie's six sequential steps for the deductive approach it was necessary, after collecting appropriate data, to measure the concepts and analyse them. By creating measurements relevant to NDM frameworks it was possible to reference themes against appropriate theory, allowing comparison for consistency with the premises of the theory. Blaikie's Final step states: *"if the results of the analysis are consistent with the premises, then the theory is corroborated".*

For the data to be operationalised, allowing facts to be measured, it was necessary to context the interviews against the output from OR's. Due to the wealth of data inherent in a company safety reporting system, it was necessary to employ the principle of reductionism to simplify the reference elements as a means of comparison. The data sift focuses quantitively on reporting rates, reporting totals and categorisation, but also assessing the comments section of applicable reports to add context and understanding. Having access to this large number of reports allows a broader generalisation of the findings, it is recognised that the significance of this sample is still relatively small when referenced against the pilot population in the UK, however, if it is compared to the flying population in the UK during the pandemic it becomes a more significant sample (Howitt, 2019).

Although seen as a generic approach to analysing qualitative data, thematic analysis was deemed the most appropriate approach Braun and Clark (2006) argue that it offers an accessible and theoretically flexible approach to analysing qualitative data. Thematic analysis was an attractive methodology for this project specifically because it could help identify key themes or patterns that would be available for further exploration, additionally, it will allow a thematic description of this data allowing explanations within the context of the current NDM theories.

3. Key Findings

The results of this research have been separated into two sections. The first section will deal with the qualitative data obtained through the interviews with six experienced long-haul captains. It will describe the results obtained through thematic analysis and explain where necessary how the categorisation has been developed. The second section will contain the data extracted from a UK long-haul airline's Safety Reports, due to confidentiality constraints it will only be possible to reproduce macro data, anything that could potentially identify a crew, or an individual has not been included. In the analysis section, both sets of data will be considered together where appropriate.

3.1. Primary Data Results/Pilot Interviews

In an aviation operational environment decisions can follow two primary structures, the first is the implementation of a Standard Operating Procedure (SOP). This is a drill or plan that has been devised by the Operator/Regulator/Manufacturer to create a trained and sanctioned crew "pathway" to achieving a defined output. The SOPs are used for many activities in the Flight Deck including pre-engine start, engine failure after take-off, a depressurisation event and after landing checks etc. An SOP is a fundamental methodology to operate an aircraft, the pilot’s decision framework within this strategy is to identify when to undertake the pertinent SOP to be actioned, and ensure it is undertaken accurately. When analysing the interview output it became evident that there had been a change to SOPs by operator/regulator/government to deal with the challenges brought about in a COVID-19 environment, it was therefore important to ensure this was reflected as a theme when considering factors that impact decision making. Additionally, interview content suggested that there was an element of workarounds and non-compliance associated with SOP methodology and this was also considered significant enough to be highlighted as a theme of the analysis. It was therefore decided to categorise SOPs into Environmental Impact and Environmental Adaptation.

In situations where SOPs are not the primary structure for decision making, for example when deciding on a diversion airfield to disembark a sick passenger, there is a broader decision-making strategy that encompasses a multitude of factors undertaken in a team environment, often with unclear or imprecise information. It was noted during the interviews that strategies considered pre-COVID-19 and COVID-19 schemas, these had some significant differences and therefore it has been useful to separate this data into two separate themes of decision-making: In-Flight Strategy Impact and In-Flight Strategy Adaptation.

Theme	**Primary Descriptor**	**Secondary Descriptor**
SOP: Environmental Impact	SOP Modified for Operations Regulators Risk Appetite changed MEL Strategy Modified	Extended FTLs Additional Dry Ice Allowance Mask Wearing on a/c Pre- Flt Test Regime (COVID-19)
SOP: Environmental Adaptations	Biased to get out of China More “go” minded Normal Rules have changed	Extra Fuel Mask Removal ATC short cuts MEL/FTL Discretion
In-Flt Decision-Making Strategy: Impact	Airfield Infrastructure and Support National Importance Keep in “known” Environment	Captains making a decision with less support Fast-changing country rules including refusal to land Deliberate “isolation” of COVID-19 factor
In-Flt Decision-Making Strategy: Adaptations	Modifying DM for China Managing Fatigue Risk profile modified for Diversion strategy	Fly West Orientation Rule Interpretation Integral team approach “Streetwise” operation

Table 1: Thematic Analysis of Decision-Making Strategy.

3.2. Interview Summary

It was believed by the candidates that there was an element of change to the baseline regulations allowing a higher risk profile, this was highly corroborated in the Flight Time Limitation extension, wearing of masks and pre-flight COVID-19 testing categories. SOPs were adapted to ensure the new requirements within the operation were protected, however, the modifications made locally, in situ, were considered by the pilots to enhance the safety of the flight whilst undertaking operations in a changing environment. Whether this was modified fuel decisions, an extension of duty period or mask removal, each decision was carefully considered and justified as part of a balanced individual assessment by the captain.

The inflight environment had changed significantly, particularly in the far east. Decision framing using familiar reference points was undertaken with the knowledge that any deviation from the routine element of the flight would carry a degree of uncertainty. This was exacerbated by long duty times and constantly changing international COVID-19 regulation. Despite diligent efforts from the various company HQs, the size and scale of operational difficulty encountered by crews going east necessitated a different approach from normal operations. This manifest itself in modifications to previous in-flight strategies, en-route airfield selection and risk profiles. This was accompanied by a collegiate approach to decision-making ensuring the more complex picture was fully considered before action.

3.3. Secondary Data Results and Air Safety Reporting Data Analysis

It was possible to access and obtain Occurrence Reports (OR) and Mandatory Occurrence Reports (MOR) for the period of 2019 (pre-pandemic) through to 2021. This gave an insight into a normalised year of reporting in 2019 and compared it to 2020 which had the most significant restraints imposed on travel and operation, through to 2021 which saw an opening of world markets including the USA in November 2021 (BBC, 2021). The data is referenced on reporting rates per 100 sectors so will give a relative picture of pilot feedback. It also reports in absolute terms, demonstrating the constraints in the flying programme as a whole.

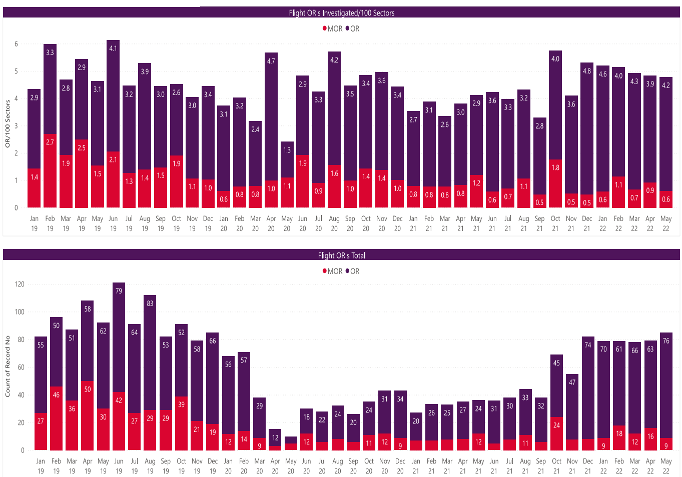

Figure 1: Occurrence Reports Per 100 Sectors and Occurrence Report Total. Jan 2019/May 2022.
*****Note 2022 data is for context only and did not form part of the analysis.

As can be seen from Figure 1 there was no significant dip in the rate of reporting throughout 2020 except for March and May. Assuming that the reporting culture had remained the same, having a small sample size due to the significant reduction in flying may give some anomalies. For example, May 2020 had 5 ORs and 5 MORs (the ORs were also filed as MORs), against the reporting rate of 1.3 ORs per 100 sectors. This gives a sector count for the month of 384, about 12 flights a day. In contrast, May 2019 had 62 ORs at 3.1/100 sectors, this gave a monthly sector count of 2000, which is 67 flights per day. The average reporting per 100 sectors stayed constant during the 3-year reference period at 3.2/100 sectors. The data management changed in 2020/21 to encompass the ICAO (ICAO, no date) reference framework for ORs but this has been normalised to present the same data source for the project. The changes in rate/sector month on month did reflect a normal distribution of the safety output from the line pilots. Additionally, the subsequent ramp-up in flying in 2021 was reflected in a comparable increase in absolute numbers of ORs filed.

In addition to total occurrence reports, it was important to understand how elements of the captain's qualitative data could be referenced against reported data from a more significant sample size. As previously stated, the captains were employed by different airlines so it would not necessarily follow that the reporting trends would be similar. Using three re-occurring data points it was possible to compare their reporting with that of the archived material. It was decided to use Fatigue, Failure to follow SOP, and Diversion events to undertake this analysis, these were universally reported by the interviewees as being of significant impact on their decision-making strategy.

3.4. Fatigue Events

Table 2 contains all the reports categorised by fatigue in level 2/3/4 (IATA) classification. These can be verified against a more detailed dataset available on request. A fatigue event may be linked to another event, Failure to Follow SOP for example, or as a stand-alone report.

Year	Number of Events	Total OR Events	% Of all reports
2019	39	1226	3.2
2020	31	396	7.8
2021	60	524	11.4* (9%) see note

Table 2: Fatigue Events. *Note:* 2021 contained an outlier total of 19 reports in December for fatigue in one single report category, if normalised to previous data the % of all reports would be 9.0%.

3.5. Failure to Follow SOP Events

Table 3 contains all the data related to self-reporting when a pilot has failed to follow an SOP, these reports range from late landing checklist action, to cabin ready memo not observed. It records each time an SOP has not been followed accurately. The full breakdown of reporting numbers is available on request.

Year	Number of Events	Total OR Events	% Of all Reports
2019	77	1226	6.2%
2020	38	396	9.6%
2021	40	524	7.6%

Table 3: Failure to Follow SOP.

3.6. Diversions

Table 4 contains all the diversion data for the reference years, a diversion is defined as a specific event, when, after take-off, the aircraft has not landed at the destination airfield as per the flight plan. If it took off from New York to London and returned to New York due to a sick passenger, that would be recorded as a diversion.

Year	Number of Events	Total OR Events	% Of all Reports
2019	22	1226	1.8%
2020	7	396	1.7%*
2021	13	524	2.5%

Table 4: Diversion Rate. *Note:* There were nil diversions from 1 March to 31 October 2020. The data set containing diversion data has a type, city pair and reason for the diversion. It is available on request.

3.7. Applied Behavioural Theory

Through the interview process and OR data sift it has been evident that the pandemic ops phase of 2020/21 has created unique and fundamental challenges to airline process and procedure. The regulation and oversight present during normal commercial activity has been modified to cope with numerous factors outside its control. The aircrews have also had to adapt to maintain safe and efficient practices through complex and changing government policies around the world. The captains interviewed were experienced pilots who had similar although not identical views on coping strategies and task management. It could be considered that there was a complex blend of decision theory identified in the sample, although no doctrine or single defined framework. Interestingly none of the pilots spoke of optimal decisions, which created the opportunity to continue to reference a Naturalist Decision-Making paradigm, based on experts seeking acceptable decisions in an action-based environment.

It was observed that a number of the captains actively sought to reference the new flying challenges within previous (routine) scenarios as an initial strategy, whether this was specifically referenced or described as “deliberately avoiding the COVID-19 factor” could amount to the same thing. As Klein's Recognition Primed Decision model relies on the decision-maker identifying critical clues that mark the type of situation and causal factors that explain what is going to happen (Klein, 2008). This is only relevant under time pressure and with relevant expertise. It may also be impacted by biases, for example, the pilots opting to fly 7 hours with an “engine out” back to base were using the reference points of the one engine out strategy but had adapted it due to a perception that landing in Russia was not a good option, although there was no evidence (unlike China) to suggest this. Russian regulations were described as "vague", but that does not define a specific risk.

Rasmussen’s Cognitive Control of Decision processes (1983) suggests that error rates are identifiable through a human malfunction in particular events or situations, he states that a particularly important type of error is a failure to recognise the need to move between different levels of rule, skill, and knowledge activity. If this is applied to the dataset obtained through interviews and OR data, it can be seen that a high level of risk (reporting) increase came through failure to follow SOP. On closer inspection of the reports, a significant number were late gear or flap selection, or speed too high in the approach phase of the flight. If this is considered alongside the data from pilots stating that ATC was applying track mile short cuts in the final approach and allowing high speed vectoring, with the data from fatigue being exponentially increased during this period it could be argued that the combination of factors prevented a change of level (Rasmussen), identify risk, and apply an alternate strategy.

A similar approach can be taken to Lipshitz's (1993) Argument-Driven Action (ADA), recognising that individuals will have different biases and heuristics it is only when a situation creates a need for resolution that requires personal experience and professional standards to be applied through a matching strategy that utilises situational assessment with experience, to this end it is similar to Kleins RPD, however, Lipshitz fundamental difference accepts that an outcome can be challenged or modified by an appropriately qualified colleague. This would enable a reassessment phase that would have the potential to modify the output. It is unlikely that this would be applied within an SOP environment, a routine or standard part of the cooperation, it would be pertinent in an in-flight scenario that required the decision to divert or continue. Interestingly the flight that turned back to Copenhagen after eight hours of flying opting not to continue to China was definitely in the definition of modified operations from a covid perspective, it was also in contact with the fleet manager at the base who would have been part of the discussion and determination of that event.

4. Conclusion

This research aimed to evaluate the underlying factors that influenced pilot decision-making whilst undertaking long-haul operations during COVID-19 and to understand if there had been a change to decision-making strategies as a result of the pandemic. Based on the qualitative analysis of pilot interviews and archived research from formal occurrence reports it can be concluded that there has been a significant adaptation to both procedures and risk mitigation, evident from the initial global response to the disease. In addition, the research sought to understand if operational and regulatory requirements impacted decision-making by the crews when managing non-normal flight operations. Based on the same analysis through interviews and archived reporting, it can also be concluded that evidence exists to suggest geopolitical decisions had a significant influence on potential outcomes in non-normal in-flight situations.

The combination of semi-structured interviews and OR data sets allowed a macro correlation to the findings, these were found not to contradict. One specific part of the decision-making around extended flight time limits and fatigue reports was particularly aligned with 100% of interviewed pilots recognising this as a challenging adaptation, and a 140% increase in ORs with fatigue output. The most obvious limitation of the findings is the function of being at a specific point in time. Very few pilots flew long haul at the outset of a pandemic, at the time a new and unknown challenge to society. It could be argued that current operations are morphing back to standard procedures and therefore this was a “point in time”, unlikely to be measured further. Set against current naturalistic decision models it could be argued that Klein (2008) and Rasmussen (1983) have parallels within aviation, RPD being a framework for situations that are novel in their manifestation. Rasmussen (1983) has more resonance with the SOP doctrine of modern airlines and manufacturers, creating structure wherever possible to standardise decision outputs. It could be argued that Lipshitz ADA is probably not a state that modern airline crews recognise as effective teamwork, it was universally expressed during the interviews that a decision is reached after consultation and input, not before, hence the adversarial nature of her theories would not be considered appropriate.

Standard Procedures were changed by both company and regulator to cope with the demands of fighting COVID-19, pilots sometimes adapted these procedures to further enhance safety. The in-flight environment was particularly impacted on flights to/from the east. The inflight challenges could not always be sufficiently mitigated by company oversight or policy. Pilots

used a variety of techniques to maintain an equivalent level of safety to the pre-COVID-19 environment.

Capturing the learnings from this research and creating value for the industry could focus on three potential opportunities:

Annual Human Factors sessions for the Air Transport Pilot Licence qualification (CAP737) rely on recent material on a range of crew resource management functions. Creating an interactive, facilitated session for annual recurrent classes based on decision making during COVID-19 would allow group contribution around some empirical data and expert opinion. Using this research as a core material for such an endeavour may help elicit further knowledge on the subject.

Line Proficiency Check and Command Training Simulator sessions for upgrade training require industry events and scenarios to educate and assess pilots undergoing promotion development. Utilising some of the scenarios outlined in this research coupled with some briefing/debriefing on elements that require non-SOP action, could be considered. Asking, can you break rules safely, would allow prospective candidates to build judgement and expertise.

Most airlines adopt a decision-making framework they advocate for crews in non-normal situations. These vary from airline to airline, what they do not consider as part of an approach to a problem is the individual biases a crew member may have, who may, or may not be sufficiently motivated to allow the bias to impact their input. It could be considered that at future crew briefings pilots are encouraged to be open about this factor. To declare that they are concerned about being locked up in China for six days because it coincides with a partner's birthday etc sounds trite. Declaring it upfront may well lead to a more open engagement. Declare your bias!

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Women In Aviation Growth

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Abstract Women remain underrepresented in the aviation sector. Current statistics indicate a substantial gender disparity in the number of pilots and engineers in the aviation sector. To achieve equality, many international organizations are advocating for more gender inclusivity in the field to ensure more women can pursue aviation careers. The COVID-19 pandemic has caused a shortage in aviation experts, opening more job vacancies for women in the sector. Although the sector has yet to achieve gender parity, more women are not participating due to gender stereotypes. Hence, governments should provide resources to support activities, including career events, workshops, and conferences, to encourage more women to pursue careers in the aviation industry.

Key Words *Women, Aviation, Gender disparity, COVID-19 pandemic.*

1. Introduction

"*If you don't have a runway, make one out of your dreams*." This quote identifies with my struggle to become an aviation expert. Being among the first Hispanic female in the corporate aviation industry has helped me to "grow a thick skin" in a male-dominated field. As a newly arrived immigrant, 23 years ago, I had to make a runway for my dreams. After all the efforts and surviving the industry's most challenging times, including the Financial crisis of 2007–2008 and the COVID-19 pandemic, I have learned that we should not accept a "no" for an answer and that no dream is impossible if we strive to accomplish it. During the last two decades, I was the only female student in each class I attended for all my ratings. This opportunity encouraged me to support and motivate new generations of women in the industry. In 2013, I earned an award for my safety and educational achievements from the Federal Aviation Administration (FAA). In 2020, during the pandemic, I received international recognition from Aero Time and a nomination as a Safety Secretary for the North American, Central American and Caribbean (NACC) Region by the International Civil Aviation Organization (ICAO). I am eager to use my experience to motivate others realize their dreams, particularly women interest-ed in pursuing a career in aviation.

2. Problem Statement, Objectives, and Research Questions

Women remain underrepresented in the aviation sector, particularly among pilots and engineers. The global community has made little progress in increasing female representation in the aviation industry. In this paper, I will demonstrate how the aviation industry is now willing and ready to accept and promote the skills and values that women can bring to the profession.

The sector is shifting to attract more women into the aviation field, thanks to the extensive participation and support of such Aviation organizations as the International Air Transport Association (IATA), ICAO, the Ninety-Nines, Women in Aviation (WIA), and the International Society of Women Airline Pilots (ISWAP). Currently, it is possible to witness the nomination and participation of many talented women in the accomplishments of the aviation industry. This research's main objective is to investigate the current growth status in the aviation sector and the trends in the industry in the post-Coronavirus pandemic era. Therefore, this research aims to investigate the growth of women in the aviation industry by focusing on the following four specific questions:

a. What is the current growth status of the female community in the aviation industry?
b. Which organizations have contributed to gender recognition in the aviation industry?
c. What is the influence of women in aviation in today's era?
d. What is the aviation industry's direction after the coronavirus pandemic?

3. Growth of Women in Aviation

Despite the number of women in the aviation sector steadily growing in the last six decades, females remain *underrepresented* in the aviation sector (see Table 1). Female pilots comprise less than 5 % of all pilots globally (see Figure 1). A similar study by Lutte (2019) revealed that women constitute less than 10 % of airline executives, pilots, and aerospace engineers. Of 163,220 pilots in the United States, there are only 6888 females, indicating that women remain a minority in the aviation industry (Halleran, 2019). India has the world's highest proportion of female pilots at 12% (Thomson Reuters Foundation, 2018). This number is twice higher than the United States and Australia. These statistics demonstrate a significant gender disparity in the number of pilots and engineers in the aviation sector.

US Women Pilots, 1960 - 2021

YEAR	Total Pilots (1)			Airline Transport Pilots (2)			Commercial Pilots (3)			All For-Hire Pilots (4)		
	Total	Women	%	Total	Women	%	Total	Women	%	Total	Women	%
2021	470,408	28,361	***6.03%***	163,934	7,698	***4.70%***	104,610	8,421	***8.05%***	268,544	16,119	***6.00%***
2020	469,062	26,854	*5.73%*	164,193	7,549	*4.60%*	103,879	7,724	*7.44%*	268,072	15,273	*5.70%*
2010	508,469	27,451	*5.40%*	136,618	5,580	*4.08%*	115,530	8,175	*7.08%*	252,148	13,755	*5.46%*
2000	532,517	24,798	*4.66%*	137,185	4,411	*3.22%*	116,051	5,807	*5.00%*	253,236	10,218	*4.03%*
1990	573,996	25,508	*4.44%*	105,650	2,082	*1.97%*	144,456	5,210	*3.61%*	250,106	7,292	*2.92%*
1980	627,238	26,896	*4.29%*	69,089	480	*0.69%*	179,449	3,993	*2.23%*	248,538	4,473	*1.80%*
1970	536,868	13,685	*2.55%*	34,351	79	*0.23%*	184,924	1,897	*1.03%*	219,275	1,976	*0.90%*
1960	252,060	4,218	*1.67%*	16,925	25	*0.15%*	93,087	738	*0.79%*	110,012	763	*0.69%*

(1) Excludes Student Pilots and Remote Pilots
(2) Since 2013, the Airline Transport Pilot certificate is required for all airline pilots
(3) Either the Commercial Pilot or Airline Transport Pilot certificate is required to fly for hire
(4) For-Hire Pilots includes all Airline Transport Pilots, Commercial Pilots, and Flight Instructors
Sources: US DOT FAA Civil Airmen Statistics, Institute for Women of Aviation Worldwide   Graphic: Jenny Beatty

Table 1: The growth of WIA in the past six decades and comparing both genders (Women in Aviation, 2022 study done by Capt. Jenny Beatty). This table shows the growth of the female community in the United States. Capt Jenny Beatty gave the author the rights to reproduce her table in order to promote awareness of the need to encourage more women to have a career in aviation.

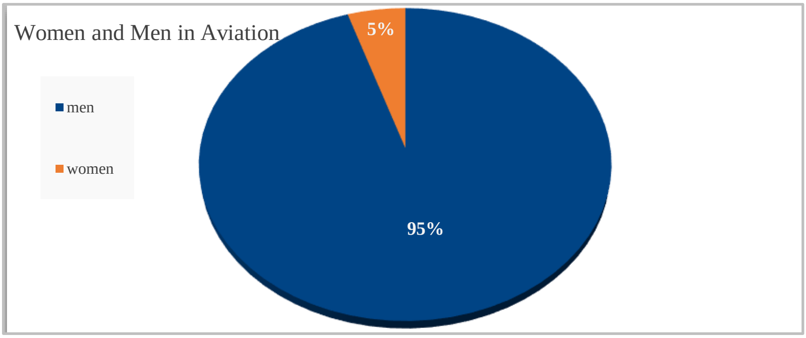

Figure 1: Proportion of men and women in the aviation industry (Thomson Reuters Foundation, 2018).

4. Organizations Contributing to Gender Recognition in Aviation

4.1. The Ninety-Nines

The Ninety-Nines International Organization of Women Pilots (The 99s) is a non-profit organization that has immensely contributed to the advancement of women in the aviation industry. Founded in 1929, the entity offers mentoring, networking, and scholarships to women in the aviation field (Ninety-Nines). The organization has played a pivotal role in promoting advancing women's inclusivity in the aviation sector.

4.2. The Women in Aviation (WIA)

The WIA is a non-profit organization that significantly influenced the advancement of women in the aviation field. It held its first conference in 1990, recognizing the need for more women in aviation (WIA, 2022). The organization also championed a support group to serve as advisors, mentors, and interested colleagues. WIA has gained global recognition because of its strong commitment to promoting the interests of women in the aviation industry. Remarkably, this recognition is evident from its notable partnerships with the FAA.

4.3. The International Society of Women Airline Pilots (ISWAP)

The ISWAP is another non-profit entity contributing to the recognition of women in the aviation sector. Founded in May 1978, this organization has evolved to offer scholarship and mentorship opportunities to women interested in an airline career. The organization has contributed to augmented female recognition in the aviation industry.

4.4. The International Air Transport Association (IATA)

The IATA encourages airlines to provide women with opportunities to help them advance their aviation careers. The organization endeavours to implement best practices to increase the participation of women in the industry, aiming to achieve a 25% attendance from female representatives in panels and conferences (IATA). It also targets to increase the percentage of women in senior positions in the aviation industry by 25 %. These efforts will improve women’s role in aviation and encourage more females to pursue an aviation career.

The 25by2025 initiative implemented by the IATA seeks to achieve gender balance in aviation and raise awareness of women's needed representation in aviation. This program aims to position women as the sector's leaders and diminish the male domination of the industry (IATA). Additionally, IATA through its Executive Leadership Program for Women in Aviation seeks to prepare new generations of women leaders in the field and helps students sharpen their knowledge and acquire the analytical skills required for senior management positions.

4.5. Influence of Women in Aviation in Today's Era

For many decades, people talked about and looked after Emilia Earhart as the pioneer of women in aviation. At that point, many thought that contemporary women would not emulate her achievements. She was the first female pilot to cross the Atlantic Ocean alone. Furthermore, Blanche Scott was the first woman pilot in the United States. These role models have opened the door for other females to emulate her in aviation. Their achievements have inspired many modern women to pursue successful aviation careers.

Nowadays, seeing women in higher positions in the aviation industry is becoming more usual. In 2021, under the leadership of the first woman secretary-general, Dr. Fang Liu, the ICAO inaugurated the campaign International Women's Day (IWD) 2021 Women in Leadership High-level Dialogue. She recognized that "*gender inequalities remain persistent in our societies and within various sectors, with gains being far from consistent*" and that "*international air transport is, unfortunately, no exception to this rule*" (Uniting Women, 2021). The campaign called upon the industry to combat gender inequality in the aviation industry by providing equal opportunities to men and women. These efforts will contribute to the industry's growth in innovation and efficiency.

Many advocates in the industry are widely recognized by social media for their diligent work in cultural evolution and more opportunities for women in the field. The magazine *Arero Time Hub* promotes a strong campaign about women in aviation besides recognizing and awarding women advocating for the new generations annually. These women advocates' influence motivates younger women to pursue aviation careers. Therefore, the publication is vital in increasing women's participation in the aviation industry.

Women have immensely influenced their participation in the aviation field. They are responsible for specific milestones in the origins of aviation. Although they have faced constant prejudice, they have contributed to some pioneer innovations in the industry. Moreover, organizations have made it easier for women to get scholarships and enroll in mentoring programs to kick-start their aviation careers. Although they still represent a small percentage compared to men, women have contributed immensely to the aviation sector. Therefore, the industry should encourage more women to pursue an aviation career to ensure equitable gender participation.

5. Women in Aviation Post COVID-19

The COVID-19 pandemic has significantly affected the aviation industry, damaging a sector already struggling to improve its diversity credentials. It has furloughed many female pilots and engineers and forced others to retire early. Consequently, the industry is currently facing a shortage of pilots. Perhaps, some decisions made during the pandemic expedited pilot shortage. For example, some airlines, including American Airlines, offered early retirement to pilots and flight attendants. This outcome resulted in the airline losing many crewmembers that would have worked for a few more years. The severe pilot shortage adversely affects air travel and airline profitability. However, this deficit has opened the door for more women to become pilots. The years 2021 and 2022 experienced significant growth in female pilots and crewmembers. For example, the most recent hiring class in Alaska Airlines was 90% women. Therefore, the COVID-19 pandemic has enabled many women to kick-start their aviation careers.

In 2021 and 2022, there was a strong presence of women pilots in the industry. For example, India led the aviation industry with the vastest representation of female pilots for decades. Thus, it is not strange to see flights operated by an all-female crew. Airlines in the Middle East also encourage female pilots' participation and recognize them for their achievements every International Women's Day. Today, women occupy managerial positions in the aviation industry, illustrating that the world is moving toward gender parity in the sector.

History shows that humans are resilient and achieve the best outcomes during challenging times, such as the coronavirus pandemic. The disease created an opportunity for women pilots and made the world take a forward step toward realizing gender equality in aviation. Not only did women show their resilience during the pandemic but also during World War II, when 1100 young civilian volunteers flew military aircraft to allow men's deployment to combat duties abroad (Stamberg, 2010). These two incidents allowed women to rise and display their strength. Ultimately, women will continue to fight for their place in the aviation industry.

6. Conclusion

Women in the aviation industry still face barriers, including discrimination, gender bias, and stereotypes, which constrain them from pursuing aviation careers. However, recent efforts by many organizations have resulted in more women professionals in the aviation industry. Currently, women have started to gain recognition in the industry after many struggles in a male-dominated field. Women leaders in the aviation sector are pushing for reforms to combat gender inequality and enable more females to pursue aviation careers. The coronavirus pandemic created a shortage of experts in the industry, which increased opportunities for women to pursue aviation careers. Consequently, 2021 and 2022 saw significant growth in women pilots, crewmembers, and engineers. Despite these accomplishments, governments need to do more work to support the development of women in aviation through robust diversity and inclusion programs. Such programs will help eradicate gender disparities in the aviation industry, allow more women to pursue aviation careers, and empower them to use their skills and talents to support the sector's overall growth.

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Talent Management: A Strategic Priority and Source of Competitive Advantage in the Aviation Industry

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Abstract The paper explores the significance of talent management strategies as adopted by the aviation industry. Quantitative research method was used to conduct the study. The research used non-probability sampling method and adopted judgement sampling technique for the study. Structured questionnaire was used to collect the data. Sample size for the research was 128 respondents. The findings suggest that market volatility and lack of passenger confidence has made it difficult to align and execute suitable talent management practices. Profit generation and essentially "making it through" the effects of COVID-19 has shaped near-future strategies and affected the feasibility of their set long-term strategies. Employee talent management has significant impact on motivation and operational performance of the employees and businesses when managed carefully.

Key Words *Talent Management, COVID-19, Motivation, Operational Performance.*

1. Introduction

Talent management concerns with the human aspect of a company; argued to be the most valuable asset for any organization. However, human resources departments today may still fail to recognize and utilize its talents. As for the employees, they can continuously improve their contributions through feedbacks, appraisals, cross-department trainings, and develop themselves to suit the needs of their organization. If performed appropriately, talent management can help employees develop their career and enter doors of opportunities. This need to be set out to them by the organization through succession planning and continuous professional development. As a result, the creation of a determined and motivated workforce increases their productivity levels and boosts organizational performance (Sabir 2017).

It is estimated that aviation jobs on an average amount to 4.4 times more productivity than any other job role in the economy. However, the air transport industry is facing numerous issues including scarcity in skilled workforce, changing business models, higher levels of competition and the global pandemic (Yiu et al. 2022). For instance, rather than long haul, sophisticated flights, passengers prefer short haul, cost-efficient flights. Many major airlines with hub and spoke models have initiated integration of point to point flights, ordering smaller aircrafts to meet local airport specifications (Lederman 2007). Additionally, pricing models have been disintegrating and airlines have struggled to gauge demand and adjust their supply levels (Wendover Productions, 2020) Considering that competition is blurring between commercial aviation; full schedule, low-cost and charter airlines, it is crucial for these businesses to revise what truly identifies as their competitive advantage.

The swelling issues within commercial air travel prior the pandemic, COVID-19 has placed the aviation industry into a further extreme fragile state – suffering the most from international flight restrictions, quarantines and lockdowns. With reasons to cause more fluctuations in demand and supply, the workforce of the industry is kept at a limbo state wherein job security and productivity is on the line. International Air Transport Association (IATA) suggest carriers today continue to burn an estimated of $5 to $6 billion dollars to keep their base operations running The Economist

(2021). Therefore, talent management during such times is even more critical as employees are expected to remain productive, determined to adapt to sudden changes and effectively contribute to keeping the company they work for afloat.

Justification
The study was undertaken to explore the Human Resource Management (HRM) concepts in aviation industry and how they are applied and incorporated by aviation companies in the United Arab Emirates UAE.

2. Methodology

2.1. Research Approach

Research design: The paper adopted the non-probability sampling using quantitative research method to examine the variables influencing employee talent management in aviation industry. The items used to measure the variables adopt the 5-point Likert-Scale. **Hypotheses of the study:** Following hypotheses were derived for the study:

H1 – The dimensions of Talent Management towards achieving competitive advantage is significant.
H2 – Talent Management has a significant impact on employee motivation and operational performance.

Sample and instrumentation: The study used self-designed structured questionnaire developed from validated scale and literature review to collect primary data. The questionnaire was divided into two sections; section 1 covering the demographic variables and section 2 covering research objectives. All the questions were close-ended. The questionnaires were distributed to 250 aviation employees. Total responses received were 189. Out of the 189 responses received, **128** were deemed fit for the purpose of research.
Sampling frame: The sampling frame was made up of employees within the aviation industry.
Sample size and area: The sample size was made up of 128 respondents representing several organizations within the aviation industry in the UAE.

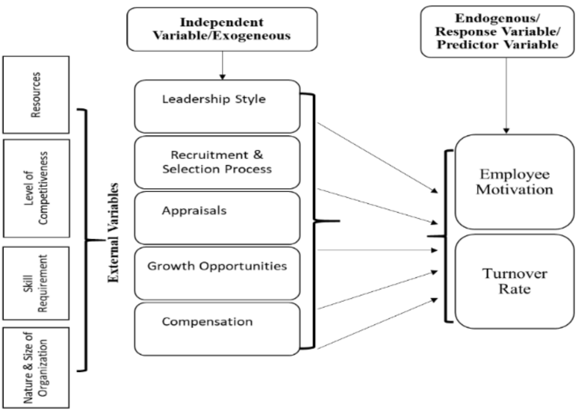


Figure 1: Model Developed to Illustrate the Variables for Employee Talent Management.

2.2. Secondary Research: Literature Review

Baqutayan (2014) and Rabbi et al. (2015) found talent management as a vital source of competitive advantage. Rofaida (2016) explored integrating an HR system that does not only acquire employees with distinctive capabilities but also optimize their talents into the organization's favor. Ibrahim et al. (2018) examined the effects of talent management and its activities in the current, competitive era. The study also investigated the perceptions of top managements on talent management practices and how they may impact the performance of businesses. Research work had been solely based on secondary source of data generation and had been analyzed using content analysis.

Simataa et al. (2018) suggested that initiatives implemented by DCA has a positive effect in managing their strategic positions despite challenges. Nagarathanam et al. (2018) concluded that rather than discovering people that are qualified to do their tasks, enterprises require human capital that can quickly adapt to constant changes in the sector and can innovate game changing ideas since technological creations are rapidly becoming common and overwritten. Abdullah and Kavraz (2018) found that that career development practices and employee retention's relationship was at a moderate level while the development practices had also moderately impacted employee retention. Muyodi et al. (2019) concluded that corporate mentoring has created a positive impact on the employee performance and suggests that an informal, casual mentoring relationships rather than formal communication channels can be applied to support employee growth. Al Hashmi et al. (2020) found the impact of three key variables of HRM; talent management, leadership practices and employee engagement and concluded that all contribute into the civil aviation sector's success. Researchers suggest leaders and strategy organizers particularly to conduct contextual analysis on their organizations and conduct similar research to different environments to test its validity even further.

2.3. Primary Research

Descriptive statistics: Descriptive statistics such as mean, standard deviation and percentages were used for demographic analysis. The data was analysed with percentile distribution to assess the distribution of age, number of years in occupation, education.

Reliability analysis: "KMO shows sampling adequacy and appropriateness of factor analysis." Hair et al., (2007) stated that value greater than 0.50 is acceptable. Bartlett's test of sphericity is 0.00 i.e. significant, which shows the correlation among items of scale with one another. Cronbach alpha is used to rate the internal consistency (homogeneity) or the correlation of items in a test. The study conducted all these tests. Factor Analysis: Principal Component Analysis (PCA) was used as an extraction method for Exploratory Factor Analysis (EFA) followed by Confirmatory Factor Analysis (CFA) on explored and established factors.

Pearson correlation: The researcher used Pearson correlation to test five independent variables leadership style, recruitment and selection process, appraisal, growth opportunities and compensation that influenced employee motivation and turnover rate to test if a relationship existed between the independent variables and dependent behaviour.

2.4. Results of Data Analysis

The data analysis shows that the average age of respondents is 35 years and most of them are graduates working in their current jobs for more than at least 5 years. More than 50% of the respondents feel that robust HR processes such as recruitment and selection is significant but not enough. There are many other factors that affect employee motivation such as developmental opportunities, retaining strategies and supporting employees during business transition.

Most of the respondents were found to be unaware of any of the talent management strategies. Since the respondents mostly belonged to Middle and Operational levels, therefore their awareness and understanding about the topic was limited. For most of the employees, profit and revenue generation seemed more important than employee motivation and retention. The study shows that though financial compensation is one of the main motivators for the employees, it is not the only factor that decides employee motivation and stay in the organization. Employees feel that their performance improves if better opportunities for growth and development are provided by the business.

3. Key Findings

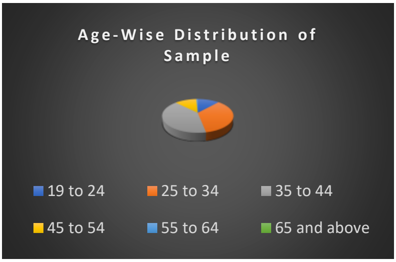
3.1. Secondary Data Results

Talent management as competitive advantage: Studies conducted across different businesses suggest that employees have become more valuable than before. Attracting, developing and retaining good employees is significant for the business sustainability**.**
Talent management in the MENA and South African aviation industry: Inconsistent leadership and lack of commitment from top management were found to be main reasons for employee dissatisfaction in this region. Profit and revenue are given priority over employees' satisfaction.

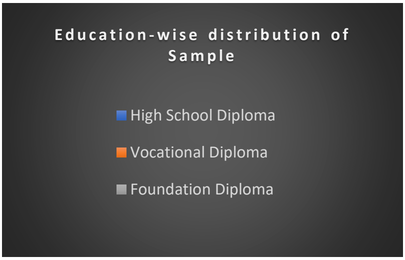
Talent management in different industries worldwide: Almost all studies found the significance of having and retaining good employees, but the strategies differ. The financial performance of the business is always given priority ahead of human resources. Employers are adopting various models to balance the employee engagement with financial returns.

3.2. Primary Data Results

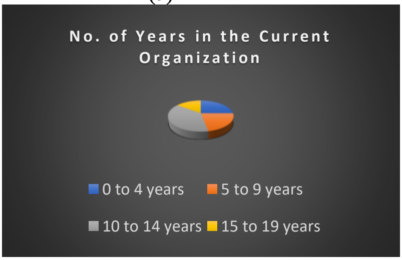
Most of the respondents were young (≈75%), educated (≈85%) and belonged mostly to middle, operational and non-managerial level (≈88%). They were found to be working in their current organizations for a considerable period. Aviation employees differ from other industries' employees in many areas such as attractiveness of the jobs, pay and benefits, work schedule, customer expectations, fatigue, dealing with complex problems etc. Therefore, the findings suggest that if the employees' aspirations are taken care of, it can have significant impact for both employees and their organizations. However, due to factors such as market volatility, change in consumer demand, changing industry dynamics and shift in passenger choices in the global aviation industry caused by the pandemic has made it difficult to gauge, align and execute suitable talent management practices.



(a)



(b)

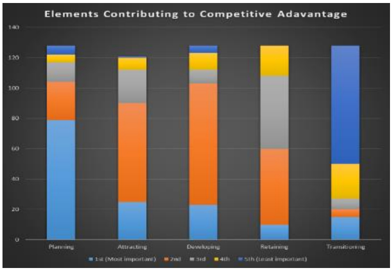


(c)

(d)

Figure 2: Demographic analysis of the sample respondents according to age (a), education (b), time in current organization (c) and level of management they belong to (d).

(a)



(b)

Figure 3: Dimensions of talent management towards achieving competitive advantage such as recruitment and selection (a) and elements contributing to competitive advantage (b).

(a)

(b)

Figure 4: Talent Management as a strategic priority (a) and other priorities the business has (b).

(a) (b)

Figure 5: Significance of talent management on employee motivation (a) and operational performance (b).

Profit generation and essentially making it though the adverse effects of the pandemic has shaped companies near-future strategies and affected the feasibility of strategies set in the long run. Managers from the sample have stated that talent management practices have resulted to improved quality of outputs. Study shows that though impact has been detected, its intensity can neither be confirmed, denied nor estimated within these two areas. Findings from the research is yet to provide strong co-relations between talent management and its impact on employee motivation and operational performance.

Collectively, this questions talent management as a company's source of sustainable competitive advantage. While findings suggest that talent management undoubtably is a source of competitive advantage when applied correctly to one's model, its longevity and stability must be reflected on – especially when linked to the Barney's Value, Rarity, Imitability, And Organization criteria (VRIO) model. With frequent shifts in strategies nowadays; from ideally differentiating themselves among their respective markets, to simply surviving the pandemic, it has affected what value talent management can be associated to and what it entirely means for businesses today.

3.3. Improving employee commitment in aviation industry

Based on our study findings, we suggest the following strategies for improving employee commitment in aviation industry.

Increase communication to clarify strategies: Being a complex industry, aviation organizations must communicate across their hierarchical structure the company's strategies and expectations from various employees. The line managers must clearly state the organization's short-term and long-term strategies to their teams.

Build; if not improve on sustaining employee commitment: Strategies, despite fluctuations and uncertainty must be recognized as feasible and within reach. A reason for employee's demotivation is unclear and unrealistic targets. Attainable objectives and instilling organizational values aligned to these objectives, in every level of the hierarchy, is a form of talent management practice that is rather intrinsic, transformational and long lasting.

Creating an effective, adaptive culture: Retaining the right employees is easier for an organization if they have reasons to connect and associate themselves to what the company stands for – which is reflected in their values and culture. The development of stronger links between employer and employee, pictures the company as a workplace where employees feel a sense of belonging and are valued in their own personal ways. Rather than a transactional relationship with their higher ups, the use of intrinsic rewards, consistency and transparency increases initiative, flexibility and authenticity in the organization (Bartlett & Ghoshal, 1994). As a result, commitment levels are increased that naturally convert into high levels of motivation and productivity. Overtime, the approach can shift businesses from a responsive approach towards competition into a proactive approach where their primary focus is the discovery of blue oceans in their respective subindustries. Embodying certain characteristics of High-Performance Work Systems can help move models in such a way that talent management does not center businesses' strategies but plays a vital role in shaping competitive strategies, helping improve their speed of adaptability and responses to change.

4. Conclusion

The findings from the study suggests that, when trying to understand the position and value of talent management in organizations, internal and external environment of the organization must be considered.

Nature of the organization: Is talent management embedded across the levels and what roles does leaders play in talent management? It is limitation in the researcher's study as the research was conducted with managers in mind rather than company leaders. Not all organizations have the capital to fund sophisticated practices of talent management especially during the pandemic where most businesses found it best to be frugal, make cutbacks and avoid huge expenses. In addition, some models discussed earlier, may be capital intensive instead of worker centric. In such cases companies may question if this is the right time to prioritize the well-being of their workforce and if it would be best to delay talent-oriented plans.

The future of talent management: The new generation of employees are different from that of previous generations. Due to technological advancements, accessibility to large sums of data and ease of gaining resources, the future workforce for most countries are young, luxurious with big aspirations and higher standards of living. It is likely that pay alone will not retain these employees as they understand their worth and contributions and have confidence that they will be able to find an employer that meets their expectations. This question the essence of talent management including employee retention strategies, development programs and motivators.

The world post-pandemic!!!: Recent studies suggest that the pandemic has set back the aviation industry at least 5 years back and is at its state in the year 2015 (Jolly, 2020). On top of this, it has also led some parts of commercial flying to never fully recover such as business class. Its full capacity prior to the pandemic will never be met again as people have adapted to video call meetings and found solutions for overlooking operations even if they are far away. Additionally, more observations are also implying that most airlines are considering shifting to a low-cost airline model as statistics indicate more stability in profit generations, access to more destinations, higher passenger demand and lesser signs of carbon emissions. (The Economist, 2021). In total, these changes can both have a direct and indirect impact on the significance of talent management and its existing approaches to organizations. Alongside the wave of new generation employees, if companies aim to overcome the pandemic and it survive the restructuring within the aviation industry itself, they must take the initiative to assess the capabilities of their existing workforce, address where they believe they may have shortcomings and establish a culture that is adaptive yet productive, that can withstand various waves in the upcoming years.

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Airlines Response to COVID-19, Stress and Employee Commitment among Flight Attendants

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Abstract The research investigated the impacts of the COVID-19 pandemic on the aviation industry and the psychological impacts on flight attendant stress levels and their perspectives on employee commitment. The results of the frequency distribution and the statistical summary display a rise in high-stress levels among flight attendants, an increase of stressors from airline strategies and a significant drop in employee commitment. Meanwhile, the correlation analysis found high a correspondence between the total stressors and salary reduction at 0.79, temporary/permanent layoff at 0.80, changes in health, and safety protocols at 0.86, risk of in-flight transmission at 0.88 and quarantine and self-isolation at 0.83.

Key Words *Flight Attendants, Stress, Airline, Employee Commitment, COVID-19.*

1. Introduction

The on-going COVID-19 pandemic challenges the aviation industry in dealing with the reduction of overall air travel demand. The International Civil Aviation Organization (ICAO) reported on the global economic impacts including the 50 percent overall reduction of airline seating capacity in 2020 and a significant shrinking of the world passenger traffic. A tremendous loss of operating revenue in the airline industry at around USD $324 billion in 2021. International travel slowed to record lows, receiving a significant reduction in air travel demand due to worldwide border closures and travel restrictions.

Throughout the course of the COVID-19 pandemic reveals the shift of the airlines' strategy from providing slogans of 'the fastest route' to 'the safest flight'. As such, many studies illustrate changes in airlines procedures such as aircraft cabin turnaround procedures (Buhusayen et al. 2020; Schultz et al. 2020), to a criteria of fit-to fly on cabin crew (Grout & Leggat 2021), the liability of passenger safety (Naboush & Alnimer 2020), social distancing in the cabin (Salari et al. 2020) and passenger flow management (Tuchen et al. 2020). However, during this time, airlines have faced extreme uncertainty and difficulty in managing positive financial flow. In 2020, over 40 commercial airlines have failed and have suspended their operations especially airlines that operated international routes who are facing challenges of international border restrictions and limits of air travel capacity.

In the short term, commercial airlines employed a mixed organizational strategy with the purpose of minimizing operating costs with factors including fleet grounding, reducing flight frequency and destinations, salary reductions, and job redundancy. With a long-term outlook, the development of high standards of health and safety in air travelling is imposed such as mask mandates in the cabin, minimized physical contact through social distancing and implemented hygienic products and services. This research explored the impacts of the COVID-19 pandemic on the aviation industry and psychological impacts on flight attendant stress levels, and perspectives toward their job commitment as well as addressed the relationship between stress levels and commitment to career, work and organizational environment.

The objective of this research is therefore:

- To establish the pattern of personal variables of flight attendants and stress, stressors, and employee commitment.
- To determine levels of stress, stressors, and employee commitment among flight attendants between before and during the COVID-19 pandemic.
- To compare the change in perception toward the impacts of the COVID-19 pandemic on stress, stressors, and employee commitment among flight attendants.
- To examine the common stressors experienced by flight attendants during the COVID-19 pandemic.

2. Literature review and Hypothesis

According to the World Health Organization (2019), stress is identified as the most significant factor leading to mental health disorders in which the aviation industry prioritises work-related stressors as a source of stress. Skybrary (2021) reported this condition within the workplace includes time constraints, the high demand for safe service, crew conflict and workload, which can significantly and consistently contribute high-stress levels for cabin crew. Chen & Kao (2011) research finds inherent problematic negative mental and physical factors within the career of flight attendants which suggest that stress may just be a natural factor of the role, despite the current research suggesting that the COVID-19 Pandemic has further increased stress levels of cabin crew to record highs. This, however, while noteworthy and true disregard the added pressure COVID-19 has had on the job and career of flight attendants (Görlich & Stadelmann 2020). A summary of the potential stressors experienced by flight attendants is shown as follows.

Airline strategies	**Stressors on employee**	**Literature**
Continuous flying during the pandemic	Increase of workload	(Görlich & Stadelmann 2020)
	Mental and physical fatigue	(Wen *et al.* 2022)
	In-flight transmission	(Grout & Leggat 2021; ICAO 2022)
Salary reduction	Financial difficulty	(Görlich & Stadelmann 2020)
Temporary and permanently laid-off	Job insecurity	(Witte 1999; Laovoravit *et al.* 2021)
Changing in health and safety protocols (uniform and service sequence)	Job mobility constrain, Increase of workload	(Khatib *et al.* 2020; Grout & Leggat 2021)
Quarantine and self-isolation	Physical and mental illness	(Brooks *et al.* 2020; Mattioli *et al.* 2020)
	Financial difficulty	(Mogaji 2020)

Although it is possible that an increase of stress could positively motivate employees and influence productivity, overwhelming stressful situations can also demolish job satisfaction, motivation, and organizational commitment. Employee commitment can be defined in many different ways. However, the most notable definition is by Meyer *et al.* (2002) who defined commitment as “a force that binds an individual to a course of action that is of relevance to a particular target” (p. 301) in which the foci of employee commitment are categorized into three main groups namely, Career commitment, Job commitment and Organizational commitment. The survey conducted by McGuire & McLaren (2009) found that environmental stressors significantly influenced employee commitment through work satisfaction. Unsurprisingly, a well-balanced employee with a healthy life balance increases the employees’ commitment. The paper published in Administrative Science Quarterly claimed that job insecurity, as well as organizational policy, were manipulated sources of commitment such as self-justification (Fox & Staw 1979).

While the existing literature on the impacts of stress and work attitudes, has not yet clearly identified a direct influence on employee commitment. Ozturk (2020) conducted a survey on Turkish airline workers including flight attendants obtaining a high level of burnout during the COVID-19 pandemic. Similarly, Grant (1996) suggests that some organizational changes can hold stressful situations for employees.

2.1. Hypothesis framework

According to the literature review, the hypothesis and research framework are as follows.

H1: *Flight attendants stress levels during COVID-19 increased from the pre-COVID 19 pandemic period.*

H2: *Airline strategies contribute more stress during the COVID-19 pandemic time*.

H3: *Airline strategies have a significant and positive effect on employee perceived stress*.

H4: *Airline strategy has a significantly negative effect on organizational commitment.*

H5: *Employee perceived stress has a significantly negative effect on employee commitment.*

H6: *Employee commitment reduce during pandemic*.

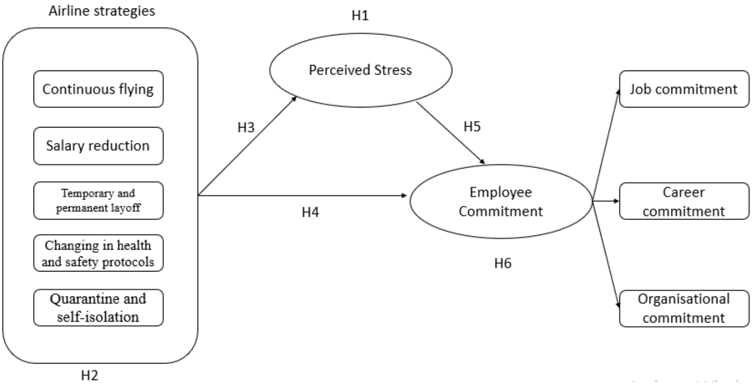

Figure 1: The hypothesis and research framework.

3. Methodology

This research employed a mixed-methods approach including quantitative and qualitative methods. The online questionnaire gathered data from flight attendants' professions using the 5-point Likert scales and open-end questions. The Likert scale range was from 1 to 5 emphasising the degree of participants' perspective while the open-end questions were used for gathering more information from participants and allowing them to express their thoughts comprehensively. The anonymous survey was distributed through the link provided on social media platforms using a convenience sampling method. The data was collected from March 2022 to April 2022. The survey measured the three main components with a total of 18 items consisting of stress (5 items), stressors (6 items), and employee commitment (7 items) in which the question was adapted from Cohen (1994), Hayday, (2003) and Mowday, Steers, and Porter (1979) respectively.

By submitting the responses online, the primary data were collated on Qualtrics and Excel spreadsheets. The frequency distribution of the initial data identified the common patterns of stress, stressors, and employee commitment among the sample, while the statistical information provides descriptive characteristics of items. Meanwhile, the difference in items scores between the pre-COVID-19 and during COVID-19 pandemic was used for correlation analysis. An investigation into the relationship between variables was employed by using multiple correlation analysis.

4. Key Findings

The final response number was 103 (N=103) consisting of 12 males, 88 females, 1 non-binary/third gender, and 2 responses who preferred not to mention their genders. The demographic information of the sample represents the cabin crew who were impacted by the COVID-19 pandemic. Overall, the majority of the sample population were women with ages ranging from 21 to 40 years old. Over 90 percent of respondents have been working as a flight attendant for more than 2 years with a full-service airline. Regarding the work position, 46.60% of the sample were cabin attendants in economy class followed by 39.81% working in business class while 13.59% had a position as a cabin supervisor.

4.1. Comparison between the Pre-COVID-19 pandemic and during COVID-19 pandemic period.

The results of the Frequency distribution and the statistical summary display the comparison of stress, stressors, and employee commitment among participants and the changing in their perception over the COVID-19 pandemic period.

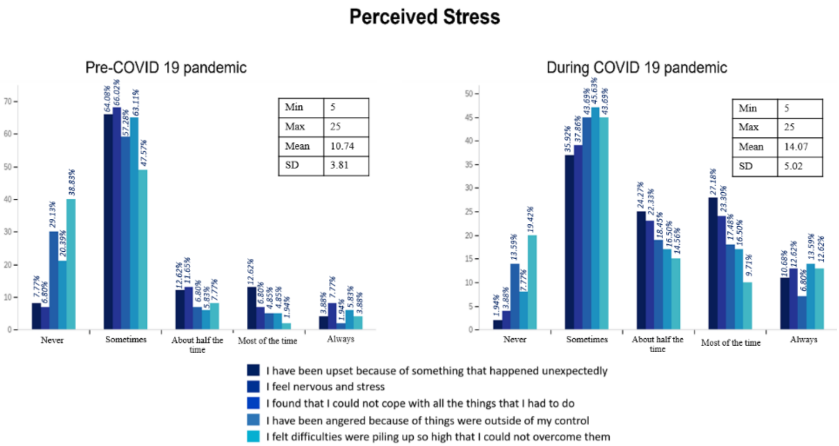

Figure 2: The distribution and statistical details of perceived stress items.

During the pre-COVID-19 pandemic period, the majority of participants perceived stress from ‘never’ to ‘sometimes’. The stress indicators include feeling upset, nervous, cannot cope with assignments, anger, and having difficulty in overcoming stress were at a low level. However, the perceived stress among flight attendants rose during the COVID-19 pandemic. The number of participants who experienced a high frequency of stress (‘most of the time’ and ‘always’) was doubled in size compared to the pre-COVID-19 period (in Figure 2). Additionally, the statistical summary demonstrates an increase in mean value in every perceived stress item as well as a rise in the total perceived stress scores. Therefore, this supports the first hypothesis that flight attendants’ stress levels during the COVID-19 increase from the pre-COVID-19 pandemic period (*H1*).

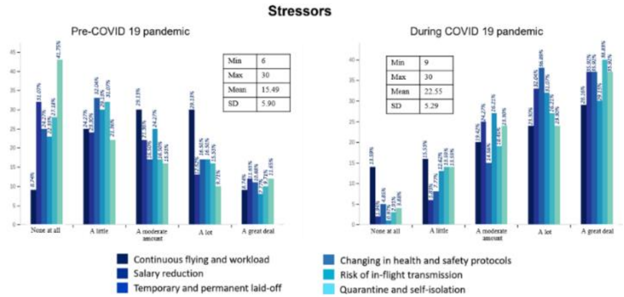

Figure 3: The distribution and statistical details of stressor items.

In terms of stressors (SS) from airline strategies, the results (in Figure 3) reveal a dramatic increase in stressors over the COVID-19 pandemic period. Prior to the COVID-19 pandemic, the continuous flying and workload (SS1) predominantly contributed to the respondent's stress, whereas the rest of the stressors including salary reduction (SS2), a temporary/permanent layoff (SS3), the changing in health and safety protocols (SS4), the risk of in-flight transmission and a quarantine/self-isolation (SS5) changed from 'not at all' to 'a little'. However, during the COVID-19 pandemic, more than half of the participants claimed that the airline strategies contributed from 'a lot' to 'a great deal' to their stress. The statistical evidence confirmed this change via an increase of mean value in the total score of stressors from 15.49 to 22.55. Thus, this supports the hypothesis that airline strategies contributed to more stress during the COVID-19 pandemic time (*H2*).

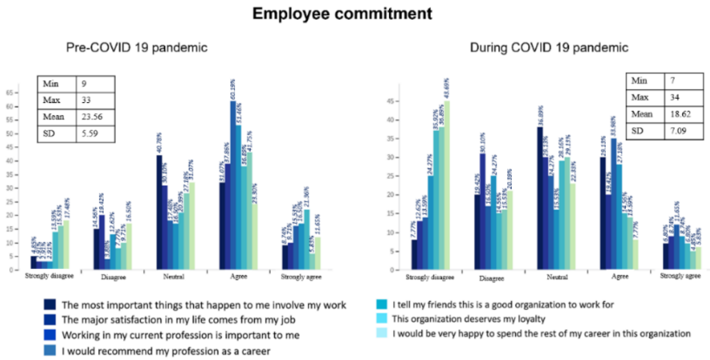

Figure 4: The distribution and statistical details of employee commitment items.

Figure 4 reveals an overall reduction of employee commitment including job, career, and organizational commitment over time. Data shows flight attendants displayed a moderate to the high level of commitment prior to the COVID-19 pandemic. In fact, over 50 percent of participants agreed that working as a flight attendant was important to them and brought them satisfaction as well as recommended their career to others. However, flight attendants' commitment dropped significantly during the COVID-19 pandemic, especially toward the organization overall. Indeed, approximately 40% of participants disagree extremely with the statement: "I tell my friends this is a good organization to work for" (EC5), "this organization deserves my loyalty" (EC6), and "I would be very happy to spend the rest of my career in this organization" (EC7). Consequently, the statistical information reveals an overall reduction of the employee commitment score from 23.56

to 18.62 as well as the data distribution spread wider since the standard deviation (SD) rose. Therefore, this supports that employee commitment was reduced during the COVID-19 pandemic (*H6*).

4.2. The relationship between stress variables and employee commitment

The results from the multiple correlation analysis illustrate the relationship among the 18 items. The correspondence between perceived stress (PS) and stressors (SS) displayed a **positive** relationship with an overall high strength of association. In other words, when the stressors value increased, the stress score also increased. According to Pearson's correlation, the coefficient value from 0.5 to 1 reflects a strong association between the two variables. Therefore, the relationship is worth highlighting, including the overall stressors (Total SS) and feeling upset (PS1) with the coefficient of correlation at 0.53. Meanwhile the increase of stressors including salary reduction (SS2), risk of in-flight transmission (SS5), and Quarantine/self- isolation highly influenced the increase of overall stress of participants as shown via the coefficient value (*r*) at 0.51, 0.50 and 0.51 respectively. Similarly, increasing in stressors strongly influenced the total stress of individuals at 0.59 as such the hypothesis, *H3: Airline strategies have a significant and positive relationship to employee perceived stress*, was accepted.

In terms of the correspondence between the perceived stress (PS) and employee commitment (EC) illustrates a **negative** correlation with moderate strength. While the perceived stresses increase, employee commitment tends to show signs of reduction. In particular, when participants feel that they cannot cope with all the things they had to do (PS3) and been angered because of things that were outside of their control (PS4) this is most likely to negatively affect their commitment overall. Therefore, we accepted the hypothesis that *employee perceived stress has a significantly negative effect on employee commitment* (*H5*) as the coefficient value between total perceived stress (*Total PS*) and total employee commitment (*Total EC*) was more than 0.5.

The results from the analysis show the **negative** correspondence between the stressors (SS) and employee commitment (EC) with moderate to high strength. Hence, the increase in stressors significantly reduced the employee's commitment. The temporary and permanent layoff (SS3) and changes in health and safety protocols (SS4) significantly reduced participants' commitment toward the organization in particular their continuous employee commitment (EC5). Furthermore, the risks of in-flight transmission (SS5) not only demotivated participants from the organizational commitment (EC5, EC6, and EC7) but it also tends to negatively impact the career commitment (EC4). The overall employee commitment was significantly influenced by the increase in airline strategy with a high coefficient value of 0.61. Therefore, we accepted the hypothesis that *airline strategies have had a significant negative effect on organizational commitment* (H4).

The summary of correlation between the stress, stressors, and employee commitment is as follows.

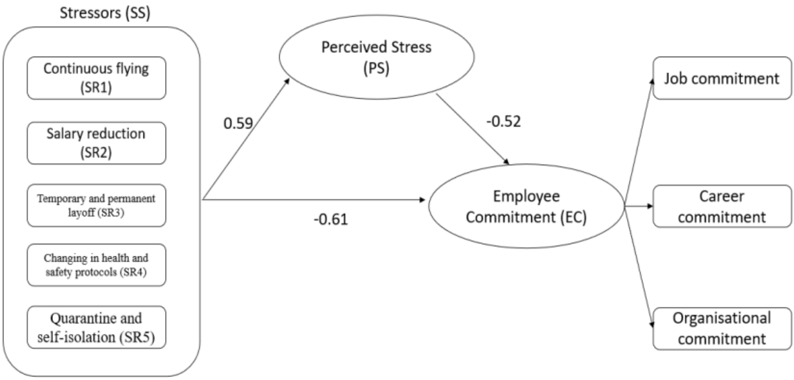

Figure 5: The summary of relationship between the stress, stressors and employee commitment.

5. Study Limitations and Further Research

This study evaluated the presented results of the flight attendant's perception over the COVID-19 pandemic period. The significance of the relationship between the airline strategies, the perceived stress, and employee commitment opens for further study into the airline stress management strategy and how it is relevant to employee attitude.

Another interesting point for further study would be to compare how flight attendants' perceptions toward stress, stressors, and employee commitment would be different in the next year or when the COVID-19 pandemic restrictions ease in their entirety. Further research could also be conducted on airline preparedness in regard to any future pandemics, in particular how mental health responses between airline employees have altered between the future and the present-day level as a result of improved management plans and the responses after the COVID-19 pandemic.
The limitations of this research include.

- This study was conducted online on particular platforms namely: Facebook, Twitter, Instagram, and Weibo. This implied a possible geographic bias as well as the personnel and social media-using habits.
- The results of this study may not measure the real-time attitudes prior to the COVID-19 pandemic as the data was collected during the pandemic period, however, this study focused on the current attitudes of respondents toward the pre-COVID-19 and during the COVID-19 Pandemic. Hence, it is possible that results found in pre-COVID 19 data cannot represent true data as a result of the lack of funding for the research.

6. Conclusion

This study revealed a significant negative impact of the COVID-19 pandemic on the perceived stress (mean scores increased from 10.74 to 14.07) and commitment of flight attendants (mean scores reduced from 23.56 to 18.62). The airline strategies such as continuous flying and workload (r = 0.28), salary reduction (r = 0.51), temporary and permanent laid-off (r = 0.40), changing in health and safety protocols (r = 0.47), the risk of in-flight transmission (r = 0.50) and quarantine / self-isolation (r = 0.51) had contributed cabin crew's stress which therefore was considered as stressors. In contrast, flight attendants reduced their commitment to their job, career and organization due to an increase in stress (r = -0.52) and stressors (r = -0.61). Therefore, the scale of this current crisis will require constant mental health monitoring from individuals as well as support from the organization.

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Job Embeddedness Theory: A Solution to the Global Commercial Pilot Shortage?

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Abstract The rapid recovery of the global aviation industry following two years of COVID-19 travel restrictions has meant many airlines are now experiencing a pilot shortage (Boeing, 2022). This paper proposes adopting Job Embeddedness Theory and recommends some actionable examples that Human Resource Managers should consider adopting within their airlines. The applicability of Job Embeddedness Theory to the retention of commercial pilots is an area that has not previously been studied. This paper contends that commercial pilots have specific characteristics that would make strategies based on Job Embeddedness Theory particularly effective in reducing their turnover.

Key Words *Job Embeddedness, Turnover Research, Commercial Pilots, Pilot Retention, Pilot Shortage.*

1. Introduction

Following the easing of COVID-19 travel restrictions during the first half of 2022, the global aviation industry has risen from the ashes with gusto (IATA, 2022), exceeding the expectations of even the most optimistic industry commentator (Dube et. al 2021). However, the speed and strength of the recovery has given rise to a challenge for the world's airlines' Human Resource Departments (HRDs): a global pilot shortage (Silk, 2022). This problem was unimaginable only 18 months ago as airlines grappled with the opposite Human Resource Management (HRM) problem of too many employees (Bidaisee and Sieunarine, 2021). With the global pilot labour resource so scarce, the pilot shortage has become the limiting factor for generating additional revenue and future growth for many pilot-employing companies. Given this new reality, the importance of attracting and retaining sufficient pilots suddenly leaps to the top of many companies' priorities, even above attracting and retaining customers. The opportunity costs, in the form of revenue foregone, of not having enough crew to fly aircraft that remain idle on the ground are considerable. This is especially true when the ticket prices have never been higher due to 3 years' worth of pent-up demand resulting in passengers paying hitherto unimaginably high airfares. A phenomenon recently referred to as "revenge travel" (Kotoky, 2022). Furthermore, given the looming cost-of-living crisis around the world, these good times must be fully exploited before airlines are once again confronted with strong headwinds, possibly even a severe recession (Taylor, 2022).

A compelling argument supports initiatives to increase the overall quantity of professional pilots worldwide. Factors like training costs, medical requirements, retirement age, gender disparity, and minimum hours are all areas ripe for scrutiny. Still, this paper's intent is not to present the case for structural change in the pilot generation system, as worthwhile as that might be. Instead, this paper takes a short-term perspective and assumes that the absolute quantity of the world's professional pilots is essentially fixed, at least for the time being. Therefore, the immediate priority for any airline is beating the competitors in the competition for the finite pilot labour resource. This means succeeding on two separate fronts: pilot recruitment and pilot retention. While these two aspects are not independent of each other, generally, the firms that can retain their pilots will also have fewer problems recruiting new ones. This paper narrows its scope by focusing only on retention strategies. In particular, a relatively recent subset of HRM and Turnover Research is called Job Embeddedness Theory (JET).

2. Literature Review

The two important themes in this paper are the nature of the Global Pilot Labour Market (GPLM) and the value of JET as a concept for tackling some of the HRM challenges that arise from employing professional pilots. This literature review will first evaluate the current academic literature concerning the characteristics of the GPLM before examining the most important literature related to JET within the field of the HRM.

The academic research related to the turnover of pilots within the GPLM is under-researched despite its obvious importance to the global economy. The few studies conducted have predominantly been concerned with the retention of military pilots rather than commercial pilots (Efthymiou et al., 2021). In 2019, Maulsby appeared to be the first to explore the theory of Job Embeddedness concerning the retention of professional pilots. Still, his paper focuses entirely on United States Air Force (USAF) aviators (Maulsby, 2019). While a useful piece of research with some useful recommendations, the sole focus on military aviators limits its usefulness and relevance. Whilst writing, Maulsby was a Lieutenant Colonel in the USAF and was posted to the Naval Postgraduate School, where he was probably required to keep his research pertinent to the United States military. The differences between military and civilian aviators' personalities are much less significant than many might presume. This is predominantly because the major militaries around the world, in times of relative global peace since World War 2, have developed a safety-first approach to aviation which has resulted in the adoption of many of the civilian airlines' practices and philosophies.

The similarities between pilots extend beyond just military and commercial pilots from the same countries. In his recent paper concerning the homogeneity of the world's pilots, Hall argues that, despite coming from different countries and diverse cultures, the attributes needed to become a professional pilot are broadly similar worldwide (Hall, 2022). Moreover, the nature of the training and the job itself promotes further homogenisation to such an extent that the world's professional pilots are remarkably similar in key personality traits, attitudes and values. While Hall's paper lacks the primary data necessary to fully support his main contention, the argument is convincing enough for one to regard the levels of homogeneity amongst commercial pilots as sufficiently high to make the GPLM different from most other global labour markets. This characteristic of the GPLM is significant because it means some well-chosen HRM strategies are likely to produce strikingly positive results amongst a cohort of pilots within a company. This is so because the usual bête-noire of Human Resource (HR) practitioners is the difficulty in devising HRM strategies that satisfy all employees because of the disparate nature of every individual employee's ambition, priorities and desires. Within most industries, this results in a whack-a-mole approach to the HRM strategy. However, it is arguably possible for HR practitioners at airlines, to hit every mole at once: it's just a matter of designing the right hammer. This paper's primary assertion is that Job Embeddedness provides the blueprint necessary for a pilot HRM practitioner to create that perfect hammer.

JET falls under the well-established field of HR studies known as Employee Retention Theory (ERT). In 2017, Hom, Lee and Mitchell co-authored a paper which comprehensively examined the previous 100 years of ERT (Hom *et al.*, 2017), describing the progression and advancements in Employee Retention and Turnover. The authors split the progress of Turnover Research into six epochs. JET did not appear until the most recent epoch of the 21st century. Still, Lee and Mitchell began contributing to ERT in the preceding decade, during the "the unfolding model" phase. Their seminal paper titled "An Alternative Approach: The Unfolding Model of Voluntary Employee Turnover" (Lee and Mitchell, 1994) laid the foundations for JET, which advanced ERT by incorporating an idea that was starting to become more widely accepted across all economic academia. Behavioural Economics is sometimes characterised as a paradigm shift within economics (Thaler, 2016), and such was also the case with the incorporation of behavioural psychology within ERT. Before this phase, most economic decision-making was characterised by the idea of rational employee choice theory first opined by Adam Smith in the 18th century.

Smith regarded employees as rational actors who should, could and would perform a comprehensive cost-benefit analysis when offered employment (Smith, 1776). This idea of rationality largely persisted in ERT until Lee and Mitchell's unfolding model examined an employee's psychological journey before voluntarily leaving a job. Most notably, this journey is characterised by human emotions rather than hard-nosed calculations. One of the most critical parts of this journey is what they describe as "shocks". A shock can be characterised as a different event that dramatically alters an employee's attitude to his/her job (Holtom *et al.*, 2005). A shock can be defined as an event that makes an employee consider leaving or "the straw that breaks the camel's back" and causes immediate resignation (Tenbrink, 2012). The numerous ways in which professional pilots are especially susceptible to shocks are explored later in this paper. While the concept of shocks was an aspect of the unfolding model that preceded JET, it is relevant to JET because, according to Burton et al., JET is the most effective antidote to shocks. After all, it serves as a buffer against the destructive potential of shocks (Burton *et al.*, 2010). A well-embedded employee can absorb shocks without it necessarily triggering voluntary turnover.

An important characteristic to understand about most of the Turnover Research before the 21st century was that its primary focus was analysing why employees left their jobs. The unfolding model is a clear case in point. However, JET's originality comes from the fact that it approaches the field of Turnover Research from the opposite direction, looking instead at the factors that cause the stayers to stay rather than analysing what causes the leavers to leave. This fundamental difference is evident simply from the titles of 2 of the most important papers written about JET. Mitchell's seminal paper from 2001 was the first to mention JET; it was titled "Why People Stay: Using Job Embeddedness Theory to Predict Voluntary Turnover" (Mitchell *et al.*, 2001). 13 years later, Lee et al. published a well-received review of JET in a paper that was titled "The Story of Why We Stay: A Review of Job Embeddedness Theory" (Lee *et al.*, 2014). Focusing on why employees stay rather than why they leave is the key characteristic of JET that sets it apart from all the previous Turnover Research. Some initially accused Mitchell of doing little more than simply examining the opposite side of the same 'employee satisfaction' coin. In other words, that embeddedness is simply a consequence of employee satisfaction, and the reasons people leave are the exact opposite of the reasons that make them stay. However, as articulated by Reitz and Anderson in their 2011 study of JET within the nursing profession, to conceptualise JET in this way is misleading (Reitz and Anderson, 2011). To illustrate this rebuttal most clearly, Mitchel et al. believe it is possible for an employee to be wholly satisfied in their job but still voluntarily leave it. Equally, they opine that an employee will not leave a job that gives them little satisfaction, provided they are sufficiently embedded.

To explain the components of JET, Mitchel et al. broke it down into three dimensions: links, fit and sacrifice. These three dimensions were split between 2 opposing contexts: Organisation embeddedness and Community embeddedness (Mitchell et al., 2001). Table 1 defines each of the six aspects from a general HRM perspective but it’s important to consider how these aspects could be uniquely relevant to the employment of pilots. For example, the significance of pilot seniority within an airline can dramatically alter a pilot’s perceived organisational sacrifice should they choose to leave. Furthermore, the community sacrifice of leaving a job can be more significant for pilots because leaving a job will often require family relocation.

Dimension	Organisation (on-the-job)	Community (off-the-job)
Fit	Reflects an employee's perceived compatibility with the organisation.	Captures how well a person perceives he or she fits into their surrounding community and environment.
Links	Formal or informal connections that exist between an employee and other people or groups in the organisation.	Recognises the significant influence of family and other social institutions and their impact on decision-making.
Sacrifice	Captures the perceived cost of material or psychological benefit forfeited when one leaves their job.	Describes the perceived cost of material or emotional benefits lost from broken links with the community when one quits their job

Table 1: Dimensions of Job Embeddedness Theory (Mitchell et al., 2001).

In recent years the academic literature concerning JET has taken a turn in 2 distinct directions. First, the drastic change in working practices since the COVID-19 restrictions has given rise to an entirely new angle that blurs the distinction between Organisation and Community embeddedness. The practice of working entirely from home and a reimagined concept of job security in the wake of widescale redundancies have both added aspects that disrupt the original orthodoxy of JET. Second, there has been an increasing propensity of academics to consider the downsides associated with high levels of Job Embeddedness. Marasi et al. were the first to ask, "Job Embeddedness: is it always a good thing?" in their 2016 paper, where they showed that organisational trust is arguably more desirable than Job Embeddedness (Marasi, et al. 2016). Subsequently, Greene et al. discussed a potential "dark side" to Job Embeddedness when they noticed a drop in employee performance due to employees feeling "trapped" (Greene et al., 2018).

3. Methodology

Using exclusively secondary data in labour economics (specifically turnover research and retention psychology) combined with the existing literature concerning the nature of the pilot labour market, this paper sits firmly at the Applied Research end of the research continuum (Saunders et al., 2009).

4. Findings

The concept of job embeddedness is not new but its usefulness in the challenge of retaining professional pilots is an unexplored area. The following are three particular features of the typical commercial pilot that have the greatest potential to trigger voluntary turnover, along with an explanation explaining how each component could be successfully countered with a JET-based initiative.

4.1. High Pay

While it may seem counter-intuitive that high pay can increase turnover, there is a logical mechanism by which this occurs. Through a combination of nature (pilot selection processes) and nurture (pilot training), pilots are often task-oriented, goal-driven, and highly conscientious individuals (Fitzgibbons *et al.*, 2004) They are likely to fastidiously plan their retirement finances well in advance, meaning that many experienced pilots will have a financial threshold necessary to retire. The better paid the job becomes, the sooner a pilot can reach this threshold. Of course, in a labour market that is short on supply, the increased demand drives up wages, allowing such pilots to achieve their savings target sooner and retire earlier, further exacerbating the short pilot labour supply. High levels of job embeddedness are a key reason explaining why experienced pilots choose to stay despite surpassing their savings target.

4.2. Relatively Little Time at Work

Commercial pilots generally spend far less time at work than most other professions. This is due to the regulatory maximum number of hours pilots are allowed to fly for safety reasons. By way of example, the maximum time a commercial pilot may fly annually is 900 hours, which equates to around 20 hours per week. Even with additional briefings and ground training time, it's unlikely that the average commercial pilot will spend more than 25 hours per week at work. Despite this relatively small amount of time at work, the fact that JET has two distinct contexts (Organisation and Community) means that it can still be highly applicable to the HRM of pilots. Given the relatively large proportion of their time spent at home, pilots will naturally place a far higher level of importance on how their home time makes them feel compared with their work time. Therefore, unlike most professions, the HRM practitioner should focus on maximising Community embeddedness amongst its pilot workforce.

4.3. Increased Susceptibility to Shocks

The role of a shock in the journey of someone who voluntarily leaves a job is often underappreciated (Holtom *et al.*, 2005). Compared to other traditional jobs, commercial pilots are especially susceptible to shocks. For example, the typical six-monthly testing regime means that every pilot is exposed twice yearly to the potential for a shock. Failing a check ride, especially if highly experienced, can cause a range of destructive, negative emotions (guilt, embarrassment, anger, vengefulness) that all have the potential to trigger a shock. Furthermore, even every routine flight can cause a surprise with the possibility of an incident or disciplinary action arising from airlines continuously monitoring flights for any pilot transgressions.

Outside of the cockpit, it can also be argued that pilots generally have an increased propensity to experience shocks compared to other professions. Owing to the reasons mostly associated with unsociable working hours and increased opportunities for infidelity, the divorce rate among professional pilots is high (Zimmer, 2014), so the likelihood of a pilot experiencing the shock of a family breakdown is increased. Finally, it is worth considering the increased potential for a personal medical shock that a pilot could experience. This comes from holding pilots to necessarily high medical standards and conducting yearly examinations to test against those standards. The loss of Class 1 aviation medical and the prospect of an uphill struggle to regain it could be the type of shock that triggers the intention to leave the profession. As discussed earlier, an employee who is highly embedded will be more likely to absorb negative shocks (Burton *et al.*, 2010) such that they simply become normal surmountable challenges rather than events which begin the leaving process, or act as the final straw for someone already contemplating resignation (Tenbrink, 2012).

5. Recommendations

While the concept of Job Embeddedness may be relatively new in labour economics, the underpinning ideas have existed in sales and marketing since the beginning of modern consumerism. Firms instinctively appreciate the value of embedding their customers into their brand and will use the full range of human psychological understanding to best achieve this goal. Still, the same effort and tactics are rarely employed with employee psychology. This distinction between staff and customers is illogical. Both staff and customers share the obvious common characteristic of being humans who make decisions that can directly affect a company's bottom line. Hence, it is the understanding of human psychology that provides the foundation upon which the concepts of brand loyalty and company trust are built, and these are essentially the same that underpin Job Embeddedness. For instance, the archetype of human embeddedness is the family unit. Most people would concede that they are more closely embedded in their family than any other group. Thus, companies try to echo this level of loyalty within their marketing. Portraying a product within a family setting, as though it is a part of the family, is a very commonly used advertising tactic for this reason. Consider how food commercials will usually depict the consumption of a food product within a family setting rather than showing someone eating by themselves. The intent is to subliminally introduce the notion that a particular product or brand is already part of the customer's family. Moreover, conflating the loyalty one feels towards a brand with the loyalty one feels towards one's family also enhances the notion that voluntarily leaving is unfathomable. This same attitude towards employment would represent the epitome of Job Embeddedness, where an employee is so embedded within their job that they cannot imagine leaving it. While it is not easy to achieve total job embeddedness quickly and cheaply for all employees, this paper makes five recommendations that apply an understanding of human psychology to quickly enhance job embeddedness within a firm, without exceptional additional HRM costs.

5.1. Exploit Data for those Personal Touches

It is high time that HR departments adopted the same focus on human behaviour as the Sales departments have for decades. Adopting such an approach should be far easier for the HRM departments, given the quantity and quality of data they already hold on their employees. The sales departments go to extraordinary lengths to obtain a fraction of that level of data to better understand their customers because they appreciate the value of sending their customers something personalised, like an email on their birthday. Personal gestures like this, from company to employee, are relatively easy to execute and could have a disproportionately positive effect on the embeddedness felt by an employee and their family.

5.2. Create a Traditional Hierarchical Structure

Nowadays, organisations (especially those employing pilots) prefer a flatter organisational structure (Cristini, Gaj and Labory, 2003), ostensibly because of the cost advantages; however, from a job embeddedness perspective, the traditional hierarchical structure offers some notable benefits. In a completely flat system, few people personally know their line manager, and managers have little emotional attachment to their subordinates. There exists little incentive to impress and no fear of causing disappointment. These are all the strong emotions one feels when tightly embedded within a traditional family unit. An entirely flat organisational structure is devoid of these emotions. Hence, pilots rarely experience the high levels of on-the-job embeddedness that come from feeling an emotional attachment to superiors and subordinates.

Furthermore, a more traditional organisational structure, with smaller teams of pilots, can create the illusion that a very large organisation is smaller and more intimate than it is in reality. It is easily possible to create the impression that a single individual is a valued member of a much smaller team, more akin to a family. Research has shown that smaller teams are generally more effective, efficient and productive (Slater, 1958). A good example of an effective hierarchical structure is evident in the majority of the world's militaries where groups of pilots are broken down into squadrons and soldiers into platoons.

5.3. Focus Primarily on the Community Embeddedness

Given the nature of a typical professional pilot's work pattern and the corresponding relatively little time spent at work, it stands to reason those measures which enhance the Community embeddedness should be prioritised by HR managers. The key element to off-the-job embeddedness is community integration. This could mean club memberships, friendship circles within the community, local voluntary work, etc. Therefore, positive measures would include any steps that can strengthen a pilot's ties with the local community. This can be especially important when an employee first joins the company and establishes their first roots in the community. Anything a company can do to strengthen these roots will help reduce turnover intentions (Dawley and Andrews, 2012). A good example of this occurs every year at universities around the world. The new undergraduates are invited to, as is called in the UK, a Freshers' Fair. This is where the various university clubs and societies gather to recruit new members during the first week of the academic year. This event is hugely beneficial for the university because new students become embedded in the university community far more quickly and deeply, hopefully shielding them from the inevitable shock of homesickness and insecurity that will soon follow. Airlines should learn from this type of event and instigate measures aimed at helping their new recruits to become more quickly and deeply embedded in the community. This could be as simple as providing a list of all the local clubs, along with contact details, when a new employee joins the company.

5.4. Focus on Facilitating Immediate Family Embeddedness

Although pilots generally spend more time at home than most other professions, shift work often means they are away from home on important dates like birthdays, Christmas or significant events for their children. During these times, it is especially important that spouses and children have strong and dependable friendship networks. These networks will sometimes not grow organically, so companies should help such networks develop. There are several ways this can be done, from organising meetups to pairing up those new in the community with those who have lived in the community for many years. The important aspect that the HRMs must appreciate is that, even if the employee is fully embedded, both on and off the job, they will still be exceptionally hard to retain long-term if their family members experience shocks without their own form of community embeddedness. Moreover, it is conceivable that a pilot with no job satisfaction - and who is not embedded within their job to any significant degree - will regardless never resign, even if offered better pay and conditions, so long as their family are deeply embedded themselves. Neglecting to promote the community embeddedness of the pilot's family will ultimately cause companies to struggle with high levels of voluntary pilot turnover. This is especially true at organisations that require a pilot’s family to relocate as a condition of employment, for example, militaries or companies that employ expatriates.

5.5. Recognise the Power of Shocks

Understanding the role and nature of shocks as part of the unfolding process is an important way to use an employee's job embeddedness to buffer those shocks. One such way is to use the data on an employee that an HRM department already stores, in order to predict their susceptibility to a shock. For example, an employee known to have a single elderly parent living a long distance away, with no siblings, is likely to experience a shock soon that could have a powerful and emotionally destabilising effect on their motivation to remain in their current employment. A cancer diagnosis in their sole remaining parent could be such an example. A proactive HRM department could recognise this likelihood and seek ways to offer early help. It might be as trivial as making a note on their file such that their line manager is already aware of their circumstances if the pilots ask for emergency leave in the future. There's a fine line between intruding into one's private life and trying to help an individual during a difficult time, but the crucial point to note is the significance of shocks in retention theory and JET and the capacity for such shocks to be prepared for and mitigated against.

6. Limitations and Further Research

It should be acknowledged that generally, some degree of turnover is desired, specifically as it can be a mechanism by which employees who are no longer a good fit for the company are replaced, but this doesn't necessarily hold when applied to commercial pilots, especially when the industry is experiencing a pilot shortage. The regular testing regime of pilots generally ensures that unsafe pilots are kept away from cockpits, so there is no need to rely on voluntary turnover to rid the company of unsuitable employees. However, a conceivable undesirable situation is that a highly embedded pilot could be detrimental to a company's efforts to retain other pilots. An individual can become so embedded that they remain in a company despite despising the job and even the company (Coetzee, Potgieter and Ferreira, 2018). Consider a single, highly disenfranchised captain's influence over numerous impressionable and lightly embedded young co-pilots. The nature of the job demands that a captain sits close to and makes small talk with the young co-pilots. At a typical large airline, a single captain could fly with up to 100 different co-pilots each year, so it is conceivable that a single begrudgingly embedded pilot (who feels more trapped than embedded) could have a much greater negative impact on overall pilot retention within a company as he persuades his co-pilots to avoid becoming a prisoner, like him. To guard against the risk of generating numerous highly embedded yet highly dissatisfied and toxic employees, companies must remain cognizant of the traditional employee satisfaction literature and not entirely neglect overall employee satisfaction in pursuit of achieving widespread job embeddedness.

Without the benefit of primary data, or even secondary data specifically investigating the usefulness of JET in relation to commercial pilots, the author's level of confidence in this paper's recommendations is naturally limited. However, the numerous existing studies in the field of JET and the discernable idiosyncrasies of the pilots' profession certainly justify further extensive research in this area. A mixed methods research project within a large commercial airline, ideally using an Action Research methodology would provide the most rigour while also retaining the flexibility to adapt to findings (Saunders et al., 2009) and any future black swan events that could disrupt the pilot labour market during the study.

7. Conclusion

The COVID-19 travel restrictions reduced demand for pilots by an unprecedented level as the skies all but emptied around the world. However, the lifting of restrictions caused a rapid resurgence in demand for air travel and pilots, with which the industry has been unable to keep pace. Airlines worldwide are now competing against each other for the limited supply of pilots, which means that pilot retention becomes paramount. Job Embeddedness Theory (JET) has grown out of traditional turnover research over the last 20 years, but its applicability to the commercial pilot labour market has not been researched. Traditional turnover research focused on establishing reasons why people leave organisations, whereas JET starts by first asking why people stay in organisations. These two approaches are not simply the same questions asked in opposite ways; job embeddedness is powerful enough to cause even the most dissatisfied employees to stay, and vice versa.

This paper showed that the Global Pilot Labour Market (GPLM) is unique in many ways and that many of these unique characteristics make it especially well-suited to Human Resource Management (HRM) policies that are rooted in an understanding of JET. There were five specific, actionable examples cited which, based on the existing literature, could yield results quickly. Still, many more possible initiatives will have JET as their cornerstone and could be discovered through a comprehensive research project within a large commercial airline.

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Tourism and Aviation: Impacts caused by COVID-19 in the Autonomous Region of Madeira (Portugal)

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Abstract Madeira airport is the main gateway responsible for the entry of passengers into the Autonomous Region of Madeira (ARM). The specific objective is to establish, through Pearson's correlation analysis, the observed behaviour of some indicators (in 2919 and 2020) on tourist activity and its relationship with air traffic. The information collected and the correlations results shows a crucial importance of air transportation for the tourism activity in ARM. The results collected and the correlations shows that there is a clear indication that Air Transport and Funchal's Airport are very important, even imperative players in the region's tourism development.

Key Words *Madeira, Capacity, Air Transport, Airport, Tourist.*

1. Introduction

The Autonomous Region of Madeira (ARM) is an archipelago of volcanic origin, located in the North Atlantic, in a region known as Macaronesia, about 450 kilometres north of the Canary Islands and 500 kilometres west of Morocco and about 1,000 kilometres from Mainland Portugal (Lisbon). The region includes two islands, Madeira, and Porto Santo, and two uninhabited groups, the Desertas and the Selvagens. The ARM is made up of 11 municipalities and 54 parishes (10 municipalities and 53 parishes are located on the island of Madeira and the rest on the island of Porto Santo) (Madeira.best, 2021).

The resident population is 254.157 inhabitants in Madeira, representing 2.5% of the country's resident population. In terms of tourist accommodation Madeira has 1,194 units, a share of 20.5% of the total accommodation in the country. Regarding the number of guests, Madeira recorded 1,617,208 guests in 2019, (a weight of 6.8% from a total of 23,953,765 in mainland Portugal) (FFMS, 2019).

Madeira's Cristiano Ronaldo Airport, also known as Funchal or Santa Cruz Airport, opened on July 18th, 1964. It is one of the most important in Portugal and serves the island of Madeira but also operates domestic and international destinations, mainly within Europe. TAP Air Portugal is the airline that most serves Madeira airport with seven daily flights from Lisbon and two daily flights from Porto (Aeroportodamadeira.pt, 2022).

According to ANA – Aeroportos de Portugal, airport authority that manages all main airports in Mainland Portugal, Madeira and Azores, the effects of the COVID-19 pandemic in 2020, brought drastic reductions in the number of passengers in Madeira airport with a drop of 65.2% against Lisbon with a decrease of 70.3%. In the same period, the movement of aircraft at Madeira airport saw its capacity reduced by 52.3% and Lisbon by 60.1%. In the network of all ANA airports the number of passengers decreased by 69.6% and the number of movements in relation to 2019 fell by 57.5% (ANA, 2021, p. 12).

The island regions, for being geographically more remote, very dependent on air and sea transport, are always good reasons to understand about their resilience, as it is the case of the ARM in the European space. Since it is a region of with political independence (Autonomous Region), there is also the perception of understanding how the responses were caused and especially the impacts in the tourism sector. The contribution of the tourism sector to the regional GDP represents between 25% and 30% of RAM's GDP and accounts for about 12% to 15% of the jobs created in the region (ARDITI, 2015).

As of February 2020, a rapid spread of the virus appeared at European level, with a special incidence in France and Italy. Due to the growing number of positive cases in the world, on March 11, 2020, the World Health Organization (WHO) declared a pandemic alert for the first time since 2009 (WHO, 2020). In Portugal, the first case was registered on 2nd March 2020 with the first state of emergency decreed on March,18th, leading to mandatory confinement and restrictions on circulation on public roads, closing borders, restricting airspace, among other measures (DN, 2020).

The limitations imposed at borders and mainly in the transport sector, especially in commercial aviation, had severe consequences in tourism and transports. Globally, tourism activity in Portugal decreased significantly in terms of overnight stays (-74.9% than in 2019) as well as at airports (-69.9% compared to 2019). In the same period, Madeira recorded -66.2% in overnight stays and -65.2% in terms of passengers. The Azores and Madeira airports registered the smallest drops, due to their traffic profile, eminently domestic (a segment that presented a loss of operations less significant) (Abrantes & Quadros, 2022).

According to "Islands and COVID-19: Key messages from a global survey" (Sindico, Sajeva, Sharman, Berlouis, & Ellsmoor, 2020), overall islands performed very well, and their inhabitants were kept safe and away from the worst consequences of the pandemic. The pandemic has revealed the fragility of tourism, food security, health and digital infrastructure. United Nations (2021) estimated that COVID-19 caused a drop of 4.7% in GDP (Gross Domestic Product) of SIDS (Small Island Developing States) in 2020. In the same way, the European Parliament (2021), regarding the islands and ultra-peripheral territories in the European Union (belonging to 13 Member States, including Portugal) considered that the pandemic had a negative impact on island communities in terms of health crisis, job losses, food security, mobility, travel, and shipments.

Portugal has become one of the most competitive tourist destinations in the world and in 2019 registered a sustained growth in tourist activity (Santos and Moreira, 2021). The results on tourist accommodation reveal that after the first hit of the pandemic, there was a small recovery in some indicators of tourist activity, namely in the Algarve and Madeira, where tourism is fundamental, as already characterized above.

The COVID-19 pandemic has seriously affected the aviation industry, with air traffic falling by more than two thirds compared to 2019 levels. The prolonged drop in air traffic will undoubtedly have consequences for the years to come, threatening economic viability countries and companies, employment and working conditions (Delli, 2021). The number of air passengers carried dropped -60.2% in 2020 to 1,808 million (4,543million in 2019), with global revenue down -54.4%. Losses reached record values in 2020 (-137.7 billion of USD), after net profits in 2019 in the order of 26.4 billion. Regarding tourism, the behaviour was identical, with a -72.3% drop in international tourist arrivals (405 million in 2020 versus 1,466 in 2019), with revenues dropping by -63.2% in the same period (IATA, 2022; UNWTO, 2022).

In global terms, tourism had an impact and the Madeira Region was no exception (ANA, 2021). So, the main question of investigation is to understand: Is tourism in ARM also heavily dependent on air transportation?

The general objective is to evaluate the effects that the reduction in traffic had on Madeira's tourism during the year of 2020. The specific objective is to establish, using Pearson's correlation analysis, the observed behaviour (2019/2020) of the following indicators of tourist activity in ARM: a) Air traffic; b) Total number of guests; c) Number of establishments in operation; d) Accommodation capacity; e) Net occupancy rate (bed); f) Average stay; g) Number of overnight stays; h) Personnel costs; i) Total revenue from tourist accommodation; j) Number of guests arriving; k) RevPAR (Revenue per Available Room).

2. Methodology

The study aims to understand the impacts (variables dependents) suffered by COVID-19, through data collected from various sources (independent variables) in selected indicators of tourist activity in ARM, taking into consideration the contextualization, relevance and interconnection between air transport and tourism as mentioned before. The approach of this study is exploratory, interpretative, and quantitative since the investigation performed and presented was obtained through observation and interpretation of statistical information. The aggregation and interconnection and the establishment of correlations between the variables will help to better understand the relationships between air transport and tourism.

A quantitative methodology was applied due to its accuracy and greater stability in the results of an investigation (Caniato, Kalchschmidt, & Ronchi, 2011). The quantitative-type methodology guarantees more objectivity in the information collected and lower costs when compared to other types of methods (Chincarini, 2014). In the statistical analysis of the data two methodologies were essentially used, the calculation of correlations using Pearson's coefficient, whose formula is shown in (2.1), and in carrying out hypothesis tests. In particular, the Shapiro-Wilk test to verify the normality of the samples under study and the t-student test to compare the mean values of two independent samples, with the computation of the p-value being used as the decision criterion.

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad , (2.1)$$

where x_i and y_i are observations of two quantitative variables and $\bar{x}$ and $\bar{y}$ are the respective sample means.

2.1. Secondary Research

The secondary data for this investigation about air transportation and tourism were obtained from the annual reports of ANA - Aeroportos de Portugal (ANA, 2021), the Portuguese National Institute of Statistics (INE, 2022), Pordata (2021) and from the Regional Directorate of Statistics of Madeira (DREM, 2021). The collected data were validated and imported into SPSS software (version 27) to perform statistical analysis. Descriptive Statistical methods were used to obtain the results presented, such as calculating frequencies, percentages, location measures, correlation analysis (Pearson's) and the creation of tables and graphs for the various variables under study.

2.2. Primary Research

Primary investigation involves an original data collection and with a mark of specificity of a research project (Gratton & Jones, 2010). The researcher collects first-hand data, not relying on literature reviews and existing data. The present investigation is based on secondary research only as characterized previously.

3. Results and Discussions

3.1. Secondary Data Results

As Madeira has an Autonomous status, the regional government was able to make its own decisions regarding restriction of COVID-19. The regional governor of Madeira has made available PCR tests released to citizens who intend to travel or disembark at Madeira airports in order to stimulate tourism.

On the 13th of March, there was an abrupt drop in traffic in Portugal, according to Eurocontrol Daily Traffic Variation - States (Eurocontrol, 2020), which impacted also the Autonomous Region of Madeira and tourism infrastructures, mainly hotel sector.

RevPAR (Revenue per Available Room) is an extremely relevant key performance indicator (KPI) to hotels. It is used to assess a hotel's ability to fill its available rooms at an average rate. If RevPAR increases, it means that the average rate of the room or the occupancy rate is increasing (Guillot, 2018). In the same way, the average daily rate (ADR) is a metric used in the hospitality industry to report the average revenue earned by an occupied room on a given day.
According to Table 1, RevPAR reduced to 52% in the first hit of the pandemic. Between April and July, the reduction remained above 85%, except for the month of July (78.9%). In August, a typical month of the tourism and hotels high season, the RevPAR reduction was smaller, however, reaching almost 62%. The year of 2020 closes with a drop of 48% registered in December.

RevPAR

Unit=Euro

	Year		Variation
	2019	2020	2020/2019
JAN	33,58	31,56	-6,0%
FEB	36,10	36,29	0,5%
MAR	42,84	20,50	-52,2%
APR	45,76	6,57	-85,6%
MAY	49,57	6,90	-86,1%
JUN	49,57	7,15	-85,6%
JUL	51,51	10,85	-78,9%
AUG	59,90	23,06	-61,5%
SEP	51,87	22,83	-56,0%
OCT	41,75	22,18	-46,9%
NOV	32,40	12,04	-62,8%
DEC	34,34	17,87	-48,0%
Accumulated JAN/DEC	44,33	22,60	-49,0%

Corresponds to all tourist accommodation establishments except local accommodation with a capacity of less than 10 beds.
Source: Drem

Table 1: Revenue per Available Room (RevPAR) in tourist accommodation. Source: Direção Regional de Estatística da Madeira (DREM, 2021).

Regarding the traffic registered at Funchal airport (Figure 1) for the years 2019 and 2020, international passengers registered a decrease of almost 70% while domestic traffic reduced to 62%. Clearly, these drastic reductions in passengers justify the drop in average revenue from tourist accommodation.

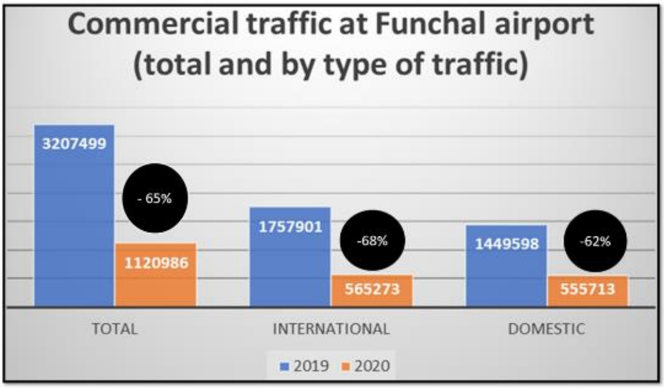

Figure 1: Funchal Airport Commercial Traffic, 2019 – 2020. Source: Own elaboration based on DREM (2021).

Regarding the national network of airports and by type of traffic (Table 2), the total number of passengers in 2020 compared to 2019 decreased globally by 69% with Funchal recording a drop of 65% (Lisbon the main Portuguese airport had a break of around 70%). Regarding international traffic, the reduction was more severe in Funchal (-68%) than in Lisbon (-66%) or relative to the airport network (-63%). In contrast, Funchal has a reduction of -62% in domestic traffic, compared with a sharper decline in Lisbon (-67%) and in the airport network (-65%). The restrictions of international mobility with several borders closed and the proximity of Madeira explained this behaviour.

Passengers 2019			Passengers 2020					
Total			Total					
Total	Lisbon	Funchal	Total	Lisbon	Funchal	Total	Lisbon	Funchal
60 114 157	31 184 594	3 207 499	18 392 550	9 267 968	1 120 986	-69%	-70%	-65%
International			International			International		
Total	Lisbon	Funchal	Total	Lisbon	Funchal	Total	Lisbon	Funchal
49 533 820	27 578 655	1 757 901	18 392 550	9 267 968	565 273	-63%	-66%	-68%
Domestic			Domestic			Domestic		
Total	Lisbon	Funchal	Total	Lisbon	Funchal	Total	Lisbon	Funchal
10 580 337	3 605 939	1 449 598	3 755 458	1 177 226	555 713	-65%	-67%	-62%

Table 2: Commercial Air Traffic Portugal´s Airport and Airfield Network (2019-2020). Source: ANA – Aeroportos de Portugal (ANA, 2021).

Figure 2 considers the international and domestic passengers on scheduled flights, as analysed previously but also the non-scheduled flights, where the domestic sector achieved a reduction of -70% and the international traffic decreased by an expressive -83%. Concerning the behavior of traffic on regular domestic flights in 2020 compared with 2019, as it can be seen in the graph (left below) that it started to fall from early March to April, due to the closure of borders and airports, followed by a very slight recovery that lasted until June. The peak in August reflects the importance of tourism season in that month starting to go back down again after that month.

With respect to scheduled flights in international traffic (right below), they pattern is similar until the end of April, and from April to June, traffic was practically at a standstill. From the end of June, it started to grow timidly until October, due to the importance of Madeira for some markets during autumn and winter season.

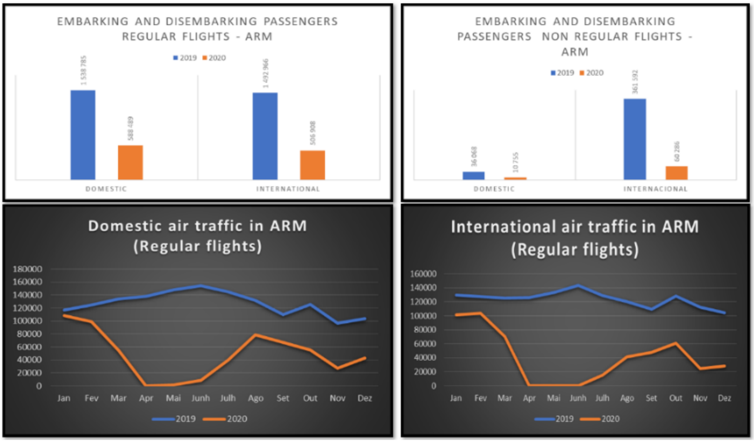

Figure 2: Passenger air traffic in Autonomous Region of Madeira – 2019/2020. Source: Own elaboration based on ANA (2021).

The analysis of Figure 3 shows the impact of COVID-19 on the number of guests entering the Autonomous Region of Madeira (ARM) was negative as of March 2020. However, it is possible to observe (top) that it existed an approximation to the number of Portuguese guests in 2019 during the months of August to October, the peak Portuguese tourism months. To compare the behaviour in average terms of the number of guests in the two years, we assessed the normality of the samples collected for this indicator and using the Shapiro-Wilk test, we concluded that the presumption of normality was verified (p-value equal to 0.708 for 2019, p-value equal to 0.352 for 2020). The t-student test allows to conclude that, on average, the number of guests entered in 2019 was significantly different from the number of guests entered in 2020 (p-value equal to 0).

Regarding the number of guests for international markets (below) the figure clearly shows the difficulties of these markets due to the pandemic moment. The application of the t-test concluded that there were significant differences in the averages of the two years both for the number of Portuguese guests (p-value equal to 0.006) and for the number of foreigners guests (p-value equal to 0).

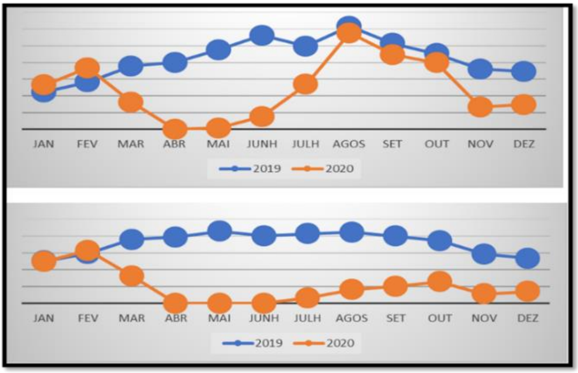

Figure 3: Number of Portuguese guests (top) and foreigners (bottom) in Autonomous Region of Madeira. Source: Own elaboration based on DREM (2021).

3.2. Correlation Analysis (Primary Data Results)

Monthly data were also collected for the years 2019 and 2020 of some indicators of tourism activity in the Autonomous Region of Madeira, namely: a) Air traffic; b) Total number of guests; c) Number of establishments in operation; d) Accommodation capacity; e) Net occupancy rate (bed); f) Average stay; g) Number of overnight stays; h) Staff costs; i) Total income in tourism accommodation; j) Number of incoming guests; k) RevPAR. Based on this information, a correlation analysis was carried out between the various indicators, using Pearson's correlation coefficient (r).

The correlation analysis of these tourist activity indicators considering the values observed in 2019 and 2020 presents some important (and at the same time some curious) results which are:

- The indicators most strongly correlated (positively) with air traffic in ARM are: Total number of guests (r = 0.919), Number of establishments in operation (r = 0.915), Accommodation capacity (r = 0.913); Net occupancy rate (bed) (r = 0.897).
- The indicators most strongly correlated (positively) with the average stay in ARM are: Number of overnight stays (r = 0.715); Net occupancy rate (bed) (r = 0.714); Staff costs (r = 0.709).
- The indicators most strongly correlated (positively) with the accommodation capacity in ARM are: Total number of guests (r = 0.858); Number of establishments in operation (r = 0.997); Air traffic (r = 0.915).
- The indicators most strongly correlated (positively) with the Total Income from tourist accommodation in ARM are: Number of overnight stays (r = 0.994); Net occupancy rate (bed) (r = 0.977); RevPAR (r = 0.992).
- The indicators most strongly correlated (positively) with Staff Costs in ARM are: Number of incoming guests (r = 0.852); Number of establishments in operation (r = 0.98); Accommodation capacity (r = 0.976).

4. Conclusion

The information collected monthly in 2019 and 2020 served as the basis for an assessment of the impacts of COVID-19 on ARM. The main objective was to understand the degree of dependence of tourism on the ARM of the existence of Air Transports. A correlation analysis was performed between the various indicators mentioned previously, using Pearson's correlation coefficient. The results permitted to understand the strong correlation between air traffic and the number of guests and overnight stays and, consequently, with its contribution to the occupancy levels of hotels. Likewise, existing capacity levels are directly linked to demand, so the air traffic variable is once again inducing the ability to generate demand and business for the tourism sector. There is consistency between the results obtained in terms of Total Income from tourist accommodation and its strong relationship with overnight stays and occupancy, which in turn impact RevPAR. Finally, fixed staff costs are directly related to the increase in the number of guests, with the increase in the number of establishments in operation and with accommodation capacity, inducers to the ability to dilute fixed costs due to their greater productive use. The absence of air transport and the absence of guests as it was visible during COVID-19 had a great impact in service activities.

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Importance of Management of COVID-19 Guidelines and Procedures

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Abstract In early 2020, the spread of COVID-19 resulted in a global pandemic. The aviation industry was heavily impacted as all of flights were suspended globally for a time period. In order to resume flights, industries and authorities determined guidelines and procedures to reduce the impact of the pandemic whilst being able to continue flying. This study aims to demonstrate the importance of management for determining appropriate guidelines and procedures to reduce the impact of pandemic. This will be achieved by using data from John Hopkins Data Centre to compare COVID-19 status in the countries the UAE, US and Bhutan. Further evaluation of these procedures and effectiveness in reducing the impact of the COVID-19 pandemic will be done by interviewing officials from Etihad Airways. The study highlights the importance of flexible standards and procedures in order to prevent COVID-19 impact on Aviation industry.

Key Words *COVID-19, Aviation, Management, Guidelines, Procedures.*

1. Introduction

The objective of this study is to demonstrate the importance of guidelines to reduce the impact of pandemic. This will be done by comparing COVID-19 cases in UAE, US and Bhutan. Each of the countries have different guidelines and procedures in place that effected the spread of COVID-19. The guidelines for each of the countries affected are shown in Table 1. differently (Jha et al., 2021). Following the guidelines had a positive impact on the aviation operations in terms of allowing for operations of flights to continue. This meant avoidance of avoid stopping operations again, like what occurred at the beginning of the COVID-19 lockdown (Keselova et al., 2020). The Aviation industry is highly impacted by the COVID-19 pandemic, for example airports in Poland suspended many operations due to the pandemic which resulted in in large financial loss (Kitsou et al., 2022). Similarly, airports in Greece were also severely impacted because passenger demand for air transportation was reduced to zero due to pandemic (Barczak, 2021). Although there were several negative effects of the pandemic on the aviation industry, there was also some positive impact such as a reduced CO2 emission. This was done to the reduced or suspended flights and air transport. It also created opportunities for more sustainable air transport especially for cargo (Bartle et al., 2021). Air transport was affected differently from other methods of transportation (Sulu et al., 2021).

Measurement for Aviation travel	UAE	US	Bhutan
Quarantine required	Yes	Yes	Yes
Vaccination required to travel	Yes	Yes	Yes
Repatriation	Yes	Yes	Yes
Social distance	Yes	Yes	Yes

Table1: COVID-19 Guidelines for the UAE, US and Bhutan.

The COVID-19 guidelines and procedures that were implemented of these countries were similar and they have focused on same measurement. However, the results and implications were different and resulted in different rates of increase in percentages of the COVID-19 cases. Results were strongly linked to the effectiveness of the management in maintaining COVID-19 guidelines and procedures.

Officials from Etihad Airways, an airline based in Abu Dhabi, have stated that the Aviation industry was heavily impacted by the global pandemic. The flight and other Aviation operations were stopped completely in beginning of the COVID-19 lockdown in March 2020. In order to return to the same level of operations pre-COVID-19. Proper guidelines and procedures were established in order to resume operations again but in a manner that reduces the risks of having COVID-19 cases in operations. They did this by establishing an initiative called 'Wellness Program' that focuses on addressing the importance of the guidelines and procedures as a part of awareness. This was done to reduce the resistance of guidelines by some people and in turn lead to all passengers abiding the guidelines thereby reducing COVID-19 cases (Etihad Airways Officials, 2022). Bhutan established a rule of 21 days quarantine in hotels required from travelers when entering the country (Tamang et al., 2021) Airlines have encouraged its employees to follow COVID-19 guidelines and procedure (Kwon, 2021). Overall, the global aim is to slowly reduce restrictions that impact the airline industry and finding guidelines that instead will enable the business and aviation operations to continue and recover from pandemic. Some guidelines such as appropriate capacity should be determined for the aircraft passengers as well as safety measurements enforced regarding hygiene (Adjie and Bahari, 2021). Social distancing should also be considered for prevention of the COVID-19 spread (Schwarzbach et al., 2020). These safety measurements should also be considered and imposed in airports (Hassan and Salem, 2021). Whilst imposing guidelines to help prevent the spread of COVID-19, maintaining good quality of service provided by carrier will ensure the continuation of its operations and success (Hassan and Salem, 2021). Services quality evaluation process changed during COVID-19 as it focused more on online reviews to be able to access to the responses and reviews during COVID-19 pandemic (Sulu et al., 2021). Updating operational procedures is important as well as having other sources of revenue (Thepchalerm and Ho, 2021).

2. Methodology

The method used to compare the guidelines followed was by observing the number of COVID-19 cases in the each of the UAE, US and Bhutan over certain time periods. The data for these COVID-19 cases was collected from published sources online. These findings of the data will also be confirmed with professionals in the industry from Etihad Airways.

3. Results

The study has several outcomes that explained the importance of the managing procedures and guidelines, especially in Aviation industry. First, we evaluated the COVID-19 cases of different countries and then compared the COVID-19 cases of all country with each other.

3.1. COVID-19 cases

Among many countries, the United Arab Emirates handled the COVID-19 situation by following certain guidelines and procedures that resulted in reducing the COVID-19 cases whilst continuing aviation operations (Elessawy et al., 2022). On comparing the data from the three countries, the United Arab Emirates COVID-19 cases were less as shown in Table 2. Table 2 shows the cases from each August since the beginning of COVID-19 pandemic until present (John Hopkins, 2022). In the United States of America, confirmed cases are more in parentage compared to other countries due to different reasons (Czeisler, 2020). One of the reasons is some of the population in the USA are against the COVID-19 vaccination or "Antivaxers" (Roberts et al., 2022). Another reason is relevant to managing resources for preventing COVID-19 especially in medical supplies and employees in healthcare sector as the shortages of these resources resulted in difficulties to prevent of COVID-19 cases from increasing (Al Thobaity and Alshammari, 2020). Many of the American airlines were highly affected because of COVID-19 pandemic as they were forced to decrease the flight operations (Carou, 2021). Another example of the impact was that Delta airline share value fell comparing to amazon which increased during the pandemic (Guo, Liu and Liu, 2021). As shown in Table 2, by determining and implementing COVID-19 guidelines, reduces COVID-19 cases. Bhutan has reduced COVID-19 cases comparing to the two other countries (showing as a percentage of the population in Figure 1) (Khandaker, 2021). The procedure for Bhutan is to trace the COVID-19 cases and the contacts who may be infected along with other strict rules. Some employees were also laid-off from their jobs temporarily in order to manage the spread of COVID-19 cases (Bhaduri, 2020). Other restrictions and procedures in place were, non-emergency air travel routes and land routes were closed (Tamang et al., 2021).

Years	US	UAE	Bhutan
2020 August	6,047,778 (1.81%)	70,231 (0.69%)	224 (0.02%)
2021 August	39,398,659(11.85%)	718,370 (7.07%)	2596 (0.33%)
2022 August	94,555,766 (28.44%)	1,015,398 (9.99%)	61,076(7.72%)

Table 2: COVID-19 cases in the UAE, US and Bhutan.

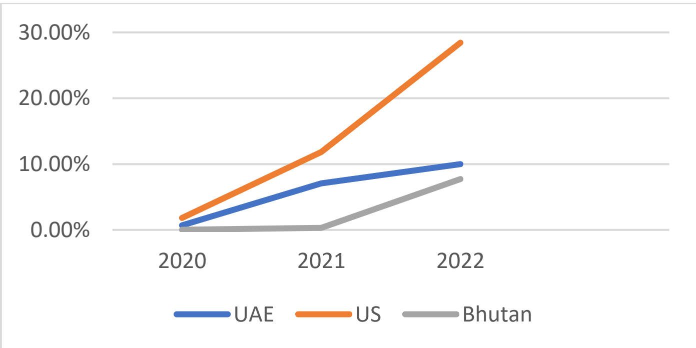

Figure 1: Percentage of COVID-19 cases comparison by country.

3.2. COVID-19 Deaths Reduction

By following the guidelines and procedures to reduce the impact of COVID-19, the deaths were reduced based on the efficiency of the guidelines and procedures adopted such as ensuring the vaccination of the population as shown in Figure 2. In the United States, the deaths increased, and vaccination rates did not cover all the population due to different reasons mentioned earlier. In the United Arab Emirates, 99.1% of its population is vaccinated and therefore they have successfully opened its borders for tourism. The spread of the COVID-19 is being controlled by maintaining the guidelines put in place at the beginning of the pandemic. The results show that this method is effective in reducing the COVID -19 impact (shown by the number of cases and deaths) (Aburumman, 2020). Bhutan, by using innovative approaches and strict COVID-19 guidelines as well as high rate of vaccination was also able to handle COVID-19 situation efficiently (Khandaker, 2021).

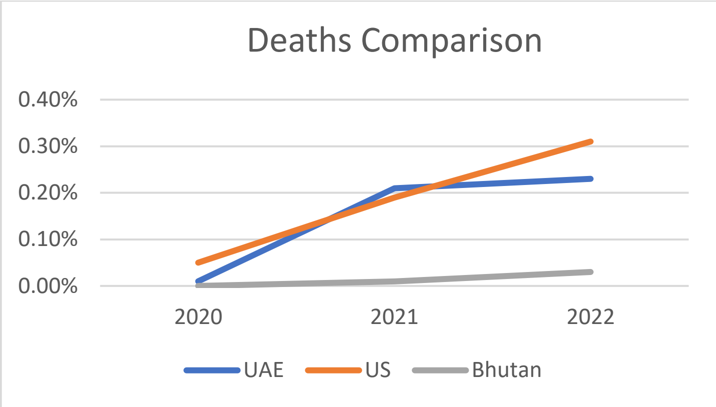

Figure 2: Percentage of COVID-19 deaths comparison by country.

3.3. Importance of management in reducing the impact of COVID-19

The forementioned countries have different COVID-19 cases these variations can be due to the total vaccinated percentage of population. The death cases explain how each country maintained the spread of the pandemic. Organisations strongly imposed strict guidelines and procedures in beginning of the pandemic and then gradually adjusted them to be less strict and more flexible. This allowed for operations and business to start again without an increase spread of COVID-19 global pandemic and the maintain the stability similar to period before COVID-19 pandemic (Vaccaro et al., 2020). It is clear, a change in management was required in order to reduce the impact of COVID-19 (Hoek, 2020). The key role of management, in particular during the pandemic, is for determining correct procedures and identifying affective guidelines that can be applicable whilst still being feasible and allowing the airlines to continue to fly. (Sun et al., 2021). One of the guidelines considered by all the airlines was requirement of the vaccination for entering their country. UAE successfully managed to encourage 99.1% of its population to be vaccinated by the explaining the importance of vaccination. It was ranked 4th for having most of its population to be vaccinated and was shown to be a leading country promoting COVID-19 vaccinations comparing to other countries (Suliman et al., 2021). In comparison, the US only successfully managed to encourage 67.89% of the population to vaccinate. The management of this vaccination programme was not as efficient as it was with the UAE (Czeisler, 2020). Similar to the UAE, Bhutan showed efficient management of the vaccination program which resulted in having 87% of its population which is a much higher percentage than the US (John Hopkins 2022).

4. Conclusion

In conclusion, appropriate management during the COVID-19 pandemic is vital in order to maintain the airline industry and prevent the spread of COVID-19. Management guidelines play an important role in providing appropriate guidelines and making sure that correct procedures are followed. This allows airlines to continue to fly and resume business. The guidelines imposed by the three countries were important factors that resulted in reducing COVID-19 cases in their countries, as the airports and airlines are the first point for the disease to spread. There was a clear difference between COVID-19 percentage of cases in UAE and Bhutan in comparison with the USA. This could be due to the differences in regulations and lower vaccination rate. This was further demonstrated by vaccination percentage of the population and deaths due to COVID-19. Overall, it is recommended to increase the awareness of community for abiding the COVID-19 guidelines and increase vaccinations in order to prevent the COVID-19 spread. The limitation of this study was the data was taken only at each month and instead it would be interesting to see this data taken over every month of the year. It would also be of interest to see the number of COVID-19 cases per month rather than the cumulative number.

5. Acknowledgements

Thanks to the officials of the Etihad Airways for the information regarding the reduction of COVID-19 impact in aviation industry and importance of increasing the awareness of community.

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Key effects of terminating short-haul routes – the Linz-Vienna example

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Abstract This paper assesses key effects of banning short-haul flights. First, alternative travel options and affected stakeholders are elaborated qualitatively. In a case study, we then analyse key effects of the actual discontinuation of the route Linz-Vienna in Austria (210 km). We find that about 25% of former Linz-Vienna transfer passengers now chose to fly via Frankfurt, instead of using ground transport to reach Vienna or alternative departure airports. For Linz Airport, a loss of 31,000 departing passengers and close to 1,500 flights per year seems to induce a revenue decline of about €3.5 million – non-aeronautical revenues not yet counted.

Key Words *Air Transport, Short-Haul Flight Ban, Austria, Linz, Airport Revenues, Traffic Impact.*

1. Introduction

At least in Western Europe, short-haul flight bans are increasingly being discussed as an alleged means to reduce the environmental impact of the air transport sector. The most prominent example of a legal ban – which has already come into force – is France. Since April 2022, airlines are no longer allowed to operate flights on French domestic routes where train or coach alternatives of 2.5 hours or less exist, unless such routes are targeted at connecting passengers (Ledsom, 2022). Other countries where such bans or similar steps have been, or are being, discussed include Austria, Germany and Spain (Cunningham, 2022). It is obvious that bans of short-haul flights will impact stakeholders along the air transport value chain, and possibly even beyond, such as regional accessibility and attractiveness.

It is the aim of this paper to identify and discuss the main effects of such bans on stakeholders, and to make use of available traffic data and airport charges information to investigate the main impacts of the discontinuation of the hub-feeder route Linz-Vienna (Liu, 2018) on key stakeholders, with a focus on traffic patterns and airport financials. We are aware that this route was already suspended before the ongoing route ban discussion; however, as this route had been ceased before the pandemic, it allows for the assessment of potential impacts without any Covid-19 bias. Limited existing work on short-haul flight bans mainly assesses the potentials to shift demand from the air transport sector to the railways from a bird's eye, macro perspective (Avogadro et al., 2021; Szymczak, 2021). However, to our best knowledge, actual effects at the airport and route levels have not yet been discussed.

This paper is structured as follows: In Section 2, we look at existing literature on (short-haul) route bans in the aviation sector. In Section 3, we illustrate key effects of route bans on travel patterns, considering the two archetypical network types point-to-point and hub-and-spoke, as well as on associated stakeholders. In Section 4, we present the applied methodologies and required information and passenger data, and estimate these effects for the Linz-Vienna route ban. In Section 5, we summarize our findings and briefly discuss additional effects.

2. Literature

Short-haul flight bans and related impacts

The air transport sector ensures international mobility at the cost of contributing about 3-5% to global warming in emitting CO_2 and generating additional non-CO_2 effects (Simorgh et al., 2022; Lee et al., 2021). In the last years, a number of measures have been introduced at different levels to reduce the sector's climate footprint. So far, these measures mainly tackle the sector's CO_2 emissions.

Most prominently and at the global level, the International Civil Aviation Organization has introduced its 'basket of measures' concept (ICAO, 2019). This "basket" includes instruments like improved aircraft technologies, operational improvements, sustainable aviation fuels and market-based measures like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Additionally, Europe is an example for a world region where additional, stronger measures like the EU Emission trading scheme (EU ETS) or ticket taxes (air passenger duties/levies) have been introduced at regional or national levels (for a comparison between the EU ETS and ticket taxes in terms of demand impact see Oesingmann (2022)).

However, many stakeholders argue that additional, stronger measures would be needed to reduce the sector's own emissions, such as kerosene taxes (e.g. called for by environmental organizations like Transport and Environment, 2020) or, as politically pushed in Austria, minimum fares (Euractiv, 2021). Probably most advanced are (short-haul) flight bans.

In April 2021, the French National Assembly passed a climate protection law which, among other things, prohibits short-haul flights if a direct train connection with a travel time of less than 2.5 hours exists on the same route (Willsher, 2021). According to Berg (2022), this new law affects former routes from Paris Orly to Bordeaux, Lyon, Nantes and Rennes, and from Lyon to Marseille, which had to be suspended, while feeder flights into the Air France hub Paris Charles de Gaulle are exempt from the regulation. In Austria, "as part of its €600m bailout from the government" in the year 2020, Austrian Airlines is obliged to shift flights to rail on routes that can be substituted by rail in less than three hours. This move apparently forced the airline to discontinue the Vienna-Salzburg route (Euractiv, 2020). Environmental lobbyists calling for such bans include Greenpeace, which demands all flights on routes where trains operate under 6 hours to be banned (Greenpeace, 2021), or a joint initiative by 14 German NGOs, led by Robin Wood e.V., which calls for a ban of flights on routes where train alternatives within 4 hours exist (Robin Wood e.V., n.d.).

So far, academic literature on this topic is limited. Szymczak (2021) assessed the impact of a potential short-haul flight ban on aircraft movements and seats at European airports, assuming no-fly scenarios for routes where train alternatives remain below 3, 4, 5 or 6 hours, respectively. Baumeister and Leung (2021) investigated to what extent the existing non-high-speed rail system in Finland could replace short-haul flights, as investments in high-speed rail are characterized by "considerable investments in time and infrastructure to build". The authors found that a switch to rail could yield in a 95% emission reduction, and that traditional railway network would remain competitive against air transport on shorter distances below 400km. It is, however, reasonable to assume that lifecycle emissions of the railway infrastructures are not considered here. Avogadro et al. (2021) assessed the substitutability of short-haul routes by ground transport modes considering both resulting increases in passenger travel time and corresponding changes in generalized travel costs. They estimate that flights representing about 3% of intra-European seats could be suspended without any significant increase in travel time for the passengers when switching to ground transport.

3. Overview of associated effects on key stakeholders

3.1. Alternative Travel options

Network types

Two key networks concepts in scheduled air transport, hub & spoke and point-to-point (e.g., Cook and Goodwin, 2008). The former is a network in which (feeder) flights are consolidated at a central hub where passengers change planes. Point-to-point networks, in contrast, are characterized by decentralized flights which solely rely on "local" demand. Consequently, a short-haul flight, which could be banned, can either be a flight to a hub, or a point-to-point operation. This has an impact on the stakeholders that would be affected.

Ban of hub feeder services

The following figure illustrates key alternatives, and affected stakeholders, for a banned hub service. Without the ban, passengers would use the hub service either to fly from their origin airport to the hub (e.g. passengers travelling from Linz to Vienna, or vice versa), or via the hub to their final destination, whereby additional connections may apply (e.g. from Linz via Vienna to Dubai, or from Linz via Vienna and Dubai to Sydney). If the hub service is banned, passengers will have the following choices (see Figure 1):

- They continue to fly from their original origin airport but use an alternative hub instead (e.g. from Linz via Frankfurt to Dubai, instead of via Vienna).
- They make use of ground transport options to get to the original hub (e.g. by train from Linz to Vienna) where they change into the air transport system (unless their final destination is Vienna).
- They make use of ground transport options to get to an alternative departure airport (e.g. by train from Linz to Munich) where they change into the air transport system.
- Other options not illustrated in the figure include a complete switch to ground transport, switching to an alternative destination airport and/or destination region, or not travelling at all.

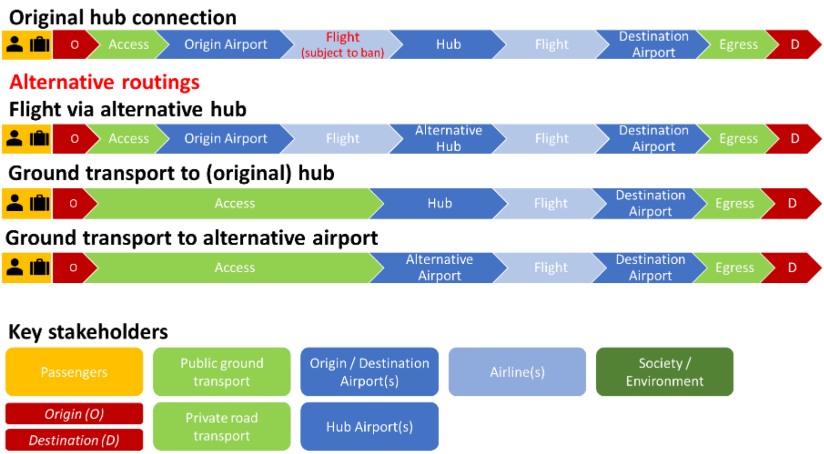

Figure 1: Ban of short-haul hub route - alternative travel options. Source: Own figure.

Ban of non-hub services

If a non-hub, point-to-point service is banned, passengers will have the following choices (Figure 2):

- They continue to fly from their original origin airport but use a hub routing instead, provided this option is not banned (e.g. from Düsseldorf via Munich to Hamburg, instead of flying directly).
- They continue to fly from their original origin airport but switch to an alternative destination airport, from where they continue by ground transport (e.g. from Düsseldorf to Lübeck instead of Hamburg).
- They make use of ground transport options to get to an alternative departure airport from where the destination airport can still be reached (e.g. from Cologne instead of Düsseldorf to Hamburg).
- They fully switch to ground transport.
- Other options not illustrated in the figure may include switching to an alternative destination airport and/or destination region, or not travelling at all.

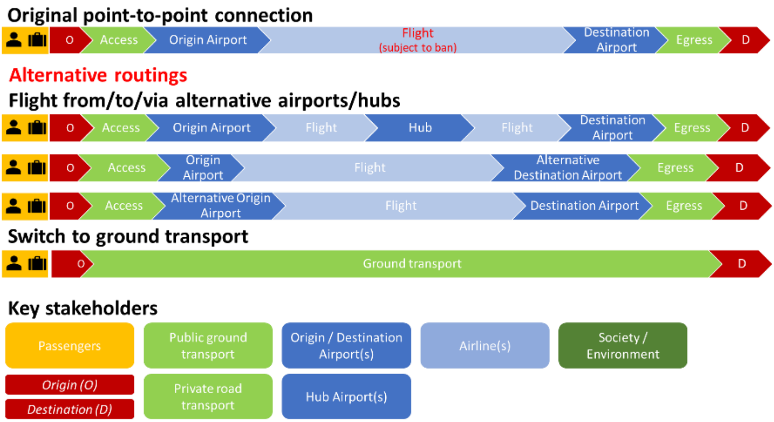

Figure 2: Ban of short-haul non-hub route - alternative travel options. Source: Own figure.

3.2. Identification of affected stakeholders

As a consequence, we identify the following stakeholders that can be affected if a route is no longer operated:

- The passenger, which is likely to be affected by longer travel times, higher fares, additional stops, additional risk of delay and connection, and inconvenient departure times.
- The original (origin, destination and hub) airports, which may experience a net loss in passenger numbers and associated aeronautical and non-aeronautical revenues (for an overview of airport revenues see, e.g., Yokomi et al., 2017).
- Any alternative airports, which may benefit from passengers being re-routed.
- The airline previously operating the banned route, which may report net losses in passenger numbers and revenues, but probably also save operating costs.
- Airlines operating alternative routes which may benefit from increasing passenger numbers and revenues.

- The public ground transport and private road transport sectors, which may benefit from additional passenger kilometres (possibly at the cost of increased congestion).

In addition, especially at the airport level, decreasing (or elsewhere increasing) revenues may cause additional effects, such as decreasing or increasing dividends at the airport owner level, or lower or higher indirect and induced employment and gross value added effects along the airport value chain.

The environment (in terms of the sector's climate impact) may or may not benefit. From a technical perspective, overall CO_2 emissions within the EU emission trading scheme (EU ETS) are capped anyway, meaning that the discontinuation of a particular service will not necessarily result in lower overall emissions. The applicability of this so-called "waterbed effect", however, depends on several factors, such as the design of the market stability reserve (MSR) which aims at cancelling unused emission allowances (e.g., Appunn, 2019). Hence, it is unclear if a ban of a certain route would eventually result in an actual decline in CO_2 emissions within the EU ETS, stationary sources included, or not.

Furthermore, the alternative usage of the aircraft that used to operate the banned route is likely to play a role. If capacities (and thus emissions) are shifted from the EU ETS area to region where no ETS or similar measure is applied, total emissions may grow. This phenomenon called carbon leakage is also acknowledged by environmental lobbyists (see, e.g. Earl and Dardenne, 2022) and would become relevant if routes within the EU ETS were replaced by routes to or between countries not participating in the EU ETS, or if an aircraft was completely transferred to the non-ETS world.

4. Key effects of a hub-feeder route ban – the Linz case

4.1. Methodology and (data) sources

We first present some background information and descriptive statistics on passenger volumes at the airport and route levels in Austria (4.2). In section 4.3, we compare the development of passenger numbers from Linz via Vienna and Frankfurt (as the only alternative hub airport served from Linz), to get an idea of how many passengers have switched to routings via Frankfurt as a replacement for Vienna following the route discontinuation. We assume that the remaining passengers now use ground transport modes to get to Vienna or to alternative airports like Munich. In section 4.4, we apply Linz Airport charges unit rates to conduct rough estimations of associated financial impacts on Linz Airport.

For this, we refer to the following data and information sources:

- Sabre Market Intelligence segment and origin-destination data
- Linz Airport, Civil Aerodrome Conditions of Use, Part II, Charges Regulation, in force as per January 1st, 2022 as approved on December 20th, 2021 by the Federal Ministry of Transport, Innovation and Technology, Department of Civil Aviation (Linz Airport, 2022)

Except for a 10% sample of airline tickets published by the U.S. Bureau of Transportation Statistics (Airline Origin and Destination Survey DB1B) (BTS, n.d.), covering the US market only, detailed origin-destination passenger volumes at the airline and routing levels are usually not available publicly. Hence, we use passenger figures provided by the chargeable Sabre Market Intelligence (Sabre-MI) database (Sabre, 2014), which consolidates MIDT (Marketing Information Data Tapes) booking data from global distribution systems with additional data from external sources and own estimates for, e.g., increasingly important direct bookings. Sabre MI provides monthly passenger number aggregates and other information like average fares both at the segment, i.e. direct route, and origin-destination (OD), i.e. routing levels.

4.2. Background

Considering scheduled air transport, the airport landscape in Austria consists of five regional or secondary airports, which are often referred to as "Bundesländerflughäfen" ("federal state airports") and account for less than 1 million departing passengers each (in 2019), and the hub Vienna. In 2019, between 7% (Salzburg) and 58% (Klagenfurt) of all departing passengers at the regional airports flew to, or via, Vienna. This equals between 50,000 and 100,000 passengers at each airport.

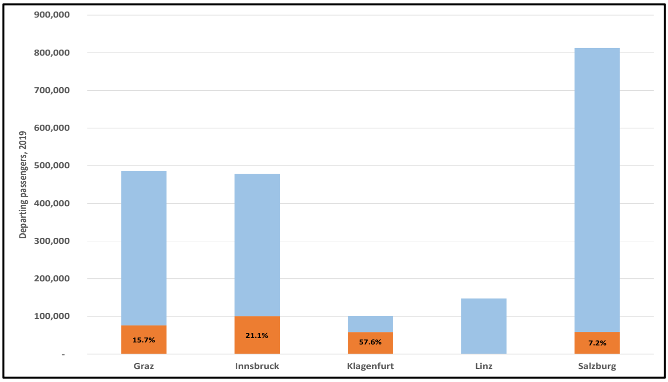

Figure 3: Bundesländerflughäfen in Austria - Departing passengers and "Vienna shares", 2019. Source: Own figure based on Sabre MI data.

In 2019, the only airport no longer connected with Vienna was Linz (in the meantime, the route Salzburg-Vienna has also been suspended, see Section 2). The following Table 1 provides an overview of current train travel times from those regional cities in Austria which have a regional airport, and Vienna Airport. Currently, Vienna Airport can be reached by train only from Linz and Salzburg in less than 2 and 3 hours, respectively, but travel times from Graz and Klagenfurt are likely to be reduced significantly over the next years.

Relation	Number of direct trains, daily, 2021	Shortest trip duration, 2021 (hh:mm)	Expected trip duration, 2028 (hh:mm)
Linz -> Vienna Airport	25	1:41	1:41
Salzburg -> Vienna Airport	22	2:49	2:49
Graz -> Vienna Airport	5	3:01	~ 2:15
Klagenfurt -> Vienna Airport	2 / (7*)	4:08	~ 3:00
Innsbruck -> Vienna Airport	11	4:40	4:40

*) The fastest travel options are the Railjet connections with a change in Vienna Central Station. The two direct connections with no changes have a journey time of approx. 6h 40min

Table 1: Railway travel times to Vienna Airport. Source: Own compilation of travel times derived from oebb.at.

As can be seen in Figure 4, the route Linz-Vienna was not discontinued immediately, but supply was step-wise reduced between 2015 and 2019, resulting in a decrease from almost 1,500 movements (up to 4 flights per day) and 41,000 passengers per year in 2013-2014 to ~550 movements and ~25,000 passengers in 2015-2016 and less than one daily flight (~260 annual movements) and about 12,500 passengers only in 2017-2018, before the route's full suspension in 2019.

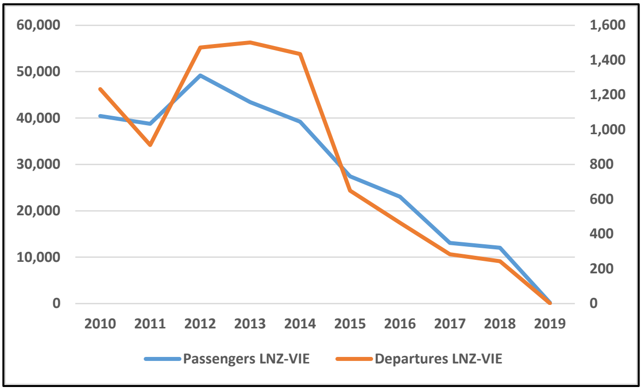

Figure 4: Flight and passenger number development, Linz-Vienna, 2010-2019. Source: Own figure based on Sabre MI data.

4.3. Impact on passenger flows

Sabre MI data, which report passenger numbers at the routing level, including connecting airports, have been used to find out how traffic patterns and intermediate hubs have changed since the gradual reduction and discontinuation of the Linz-Vienna route.

Figure 5 shows the development of the passenger flows from Linz via the hubs Vienna and Frankfurt for the period 2010-2020. In line with the reduction in supply between Linz and Vienna, traveller volumes via Vienna have decreased massively between 2014 and 2019. At the same time, the figure indicates a moderate increase in passengers via Frankfurt over time.

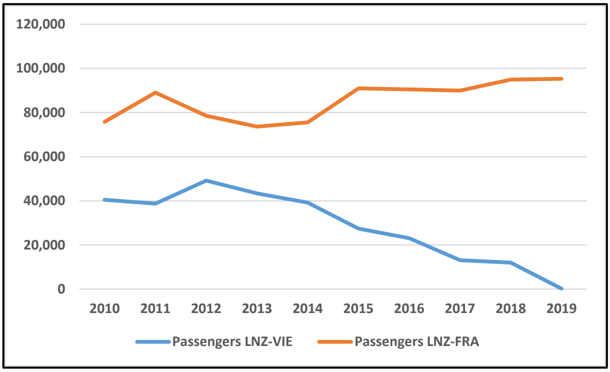

Figure 5: Passenger number development, Linz-Vienna and Linz-Frankfurt, 2010-2019. Source: Own figure based on Sabre MI data.

Table 2 summarizes the key figures for the average of the years 2013-2014, on the one hand, and the year 2019, on the other hand.

	Mean 2013-2014	2019	Effect
Passengers Linz-Vienna	41,305	0	Route suspension
Movements Linz-Vienna	1,468	0	Route suspension
Total number of connecting passengers from Linz via any hub	112,097	77,973	Decrease in connecting passengers via Vienna
Connecting passengers from Linz via Vienna	39,788	0	Switch to ground transport and via FRA
Connecting passengers from Linz via Frankfurt	66,201	76,268 (+10,085)	Generation of ~10,000 former "via Vienna" passengers

Table 2: Passenger and movement effects Linz-Vienna/Frankfurt. Source: Own compilation of data derived from Sabre MI.

The data indicate that the number of connecting passengers commencing their journey in Linz has decreased massively, from 112,000 in 2013-2014 to 78,000 in 2019, due to the complete suspension of the hub service to Vienna (which had accounted for almost 40,000 connecting passengers in 2013-2014). To some extent, however, Linz Airport managed to keep a portion of former "via Vienna" travelers – as about 10,000 (76,268-66,201) additional connecting passengers can now be reported for the Frankfurt route.

Based on this, we conclude that about ¼ of former connecting passengers flying over Vienna have switched to the Frankfurt route, while the remaining ones are supposed to use ground transport to reach either Vienna Airport, or alternative departure airports like Munich.

In this particular case, it is reasonable to assume that most of the former Linz-Vienna passengers are still flying with Lufthansa Group which had – and still has – a monopoly both on the Linz-Frankfurt and Linz-Vienna routes. Also, Linz is not served by any other hub carriers from any other hubs.

4.4. Financial impacts on the airport operator

We refer to available airport financial data to assess the financial impact of the observed passenger and movement loss for the operator of Linz Airport.

Comparing 2014/2014 and 2109 figures, Sabre MI data indicate a loss of about 1,468 departing flights to Vienna with some 41,305 passengers, while 10,085 additional passengers could be observed for the Frankfurt route. This means a net loss of 31,219 annual passengers. The weight of the aircraft that used to be operated on the Linz-Vienna route amounts to about 30t MTOM (DHC8-Q400).

According to the official airport charges regulation (Linz Airport, 2022, current charges for the discontinued Vienna route would be as follows:

- Landing charge: €19.91 / t MTOM multiplied by a "regional air traffic" factor of 85%
- Infrastructure charge "air-side": €139.72 for tariff group 5 aircraft (29-45 t MTOM) multiplied by a "regional air traffic" factor of 85%
- Infrastructure charge "land-side": €2.09 per passenger multiplied by a "regional air traffic" factor of 85%
- Passenger service charge of €18.15 per departing passenger multiplied by a "regional air traffic" factor of 85%
- Security charge of €18.41 EUR per departing passenger

- Ground handling services charges of €963.8 (ramp handling) and €643.40 (traffic handling) for tariff group 5 aircraft (29-45 t MTOM), each multiplied by a "regional air traffic" factor of 85%.

We apply these unit rates to the calculated net loss in passengers and movements to rate the annual loss in airport revenues associated with the suspension of the Vienna route:

- Loss in landing charge: 1,468 movements * €19,91 / t MTOM * 30 t * 0.85 = €745,311
- Loss in infrastructure charge "air-side": 1,468 movements * €139.72 * 0.85 = €174,343
- Loss in infrastructure charge "land-side": 41,305 * €2.09 * 0,85 = €73,378
- Loss in passenger service charge: 41,305 * €18.15 * 0.85 = €710,604
- Loss in ground handling service charge: 1,468 movements * (€963.8 + €643.4) * 0.85 = €2,005,464 EUR
- **Sum: €3,709,099**.

This loss has to be corrected by additional revenues collected from those 10,085 additional passengers flying via Frankfurt – where the 15% discount for "regional traffic" does not apply:

- Additional infrastructure charge "land-side": 10,085 * €2.09 = €21,079
- Additional passenger service charge: 10,085 * €18.15 = €183,051
- **Sum: €204,129**.

We assume that the aircraft size on the Frankfurt route has remained constant. Otherwise, additional revenues from aircraft weight-based charges would have to be considered, too.

This indicates a net decline of €3,709,099 – €204,129 = €3,504,970 in airport revenues, not including security charges and not (yet) considering non-aeronautical revenues (e.g. from parking, food and beverage, or retail).

5. Conclusion

As a reaction to an increasing carbon footprint of aviation, first European countries have introduced – or are discussing – bans on short-haul flights. We have assessed key effects of such measures on passengers and other stakeholders.

In a first step, alternative travel options, affected stakeholders and associated effects were elaborated qualitatively, considering different archetypical network and route types. In a second step, we have referred to the Linz-Vienna route (210 km) to analyse the effects of an actual route discontinuation on key stakeholders.

We find that about 25% of former Linz-Vienna transfer passengers now fly via Frankfurt, instead of using ground transport to reach Vienna or any alternative departure airports. For Linz Airport, a loss of 31,000 departing passengers and close to 1,500 flights translates into losses in aeronautical airport revenues of about €3.5 million per year.

A quantitative assessment of actual financial effects on other stakeholders was beyond the scope of this paper. For example, train operator(s) will benefit from additional passengers – and related revenues – on routes to Vienna Airport, while Vienna Airport is potentially losing (transfer) passengers not willing to use the railway connection, while, however, the discontinuation of the Linz route is likely to result in valuable slots become available for alternative routes.

In general, airlines can be affected asymmetrically by a ban on short haul flights. In our particular case, Austrian Airlines loses transfer passengers at its Vienna hub, while Lufthansa gains for connections via Frankfurt. In this case, the total impact may be considered marginal, as both airlines are part of the same group. For other airports and airlines, the competitive situation can be more serious when a competitor is allowed to serve a more distant hub, while flights to closer hubs might fall under a ban.

In future research, these – and probably additional – effects could be assessed in more detail, using primary, e.g. survey data, if available.

From the environmental perspective, it is questionable if a ban of short haul flights will lead to a reduction in CO_2 at all. In most of Europe, short-haul flights are subject to the EU ETS (Emission Trading Scheme) which puts a cap on total CO_2 emissions from intra-EEA aviation. If a flight is no longer operating, the required allowances are likely to be used for other flights, or by other sectors participating in the EU ETS. In addition, slots and aircraft of former short-haul flights could even be used for new extra-European flights, which are not subject to the EU ETS. Such environmental effects and trade-off should also be evaluated more carefully in forthcoming research. For example, actual flight movement data, which could for example be retrieved from providers like flightradar24, could help identifying to what extent aircraft were shifted to extra-EEA routes in reaction to a route ban.

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Retention Strategies and Job Satisfaction in the Post-Pandemic Workplace Environment: Evidence from the Middle East and Southeast Asia

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Abstract The human disconnection left by the pandemic caused certain tensions to rise that could affect job satisfaction and essentially, the retention of valuable employees. Though recognized, the lack of leaders addressing and minimizing frictions have increased the potentials of a disconnected workplaces and poor productivity levels, overall increasing voluntary resignation of dissatisfied employees. The study, therefore, explores how selected low-cost carriers have addressed employee retention and maintain job satisfaction in the post-pandemic workplace environment.

Key Words *Retention strategies, Aviation sector, COVID-19, Job satisfaction, Low-cost carriers.*

1. Introduction

Three years after the first cases of COVID-19, the world in 2022 is gradually showing signs of recovery and employees take steps towards bringing employees back to their workplaces (CBPP, 2022). However, due to the pandemic-driven disconnections amongst employees, new tensions have risen that have tendencies of affecting job satisfaction and the retention of valuable employees (Thomason and Franczak, 2022). These tensions such as living up to what is defined as an “ideal worker” post-pandemic, deciding on possible or preferred availability and the speed at which employees reconnect with their social circles have grown relevant to high-demand industries (including aviation) which can be associated to the lack of action by leaders to address and minimize said frictions (Poswolsky, 2022). As a result, these tensions may compound and potentially lead to disconnected workplaces, poor productivity levels, and furthermore voluntary resignation of dissatisfied employees.

The study therefore particularly aims to explore how low-cost carriers (LCCs) have retained employees and maintained job satisfaction in the post-pandemic workplace environment and whether these tensions have been recognized as a severe issue that could be linked to areas of productivity, satisfaction and organizational commitment. In order to do so, the study aims to answer the following research question: How LCCs can retain employees and maintain job satisfaction in a post-pandemic workplace environment? The study is guided by the following research objectives: 1) To identify and compare the retention strategies between two low-cost carriers situated in two countries; 2) To investigate whether retention strategies have changed prior to the pandemic and post-pandemic; 3) To determine whether retention strategies in place have significantly impacted job satisfaction and employee productivity; 4) To contribute to the literature and business practice in the area of employee retention and job satisfaction post the adverse effects of COVID-19 with focus on LCCs.

The study aims at investigating on how LCCs have realistically approached the rise in employee retention and possible fluctuations in job productivity present globally. It additionally aims to offer understanding in the areas of revised practices and procedures related to the operating of LCCs while providing contributions to airline-based Human Resource Management (HRM). HRM is defined as the “distinctive approach to employment management which seeks to achieve competitive advantage through the strategic deployment of a highly committed and capable workforce, using an array of cultural, structural and personnel techniques." (Storey, 1995).

As a result of the pandemic, just over the 2019-2020 period, the overall employee resignation had increased by 4.5% (Cook, 2021). This significant amount of employees resigning was a phenomenon evident in multiple industries (Alrawashdeh, et al., 2021; Bravo, et al., 2021) which can be recognized as a symptom of voluntary, contagious turnover (Kim and Sohn, 2022; Le, et al., 2021 and Allen, 2008) that negatively affects employee productivity.

The aviation industry as a service-driven sector was severely impacted by the pandemic with an estimated influence rate of 100% (Le, et al., 2021), particularly in the low-cost carrier sector (Kankaew et al. 2021). International Air Transport Association predicts that aviation-supported jobs will potentially fall from 44.6 million to 43.8 million over the next few years (Airlines-IATA, 2021) with the Asia-Pacific market being affected the most, followed by Africa and then the Middle East (IATA, 2021).

The Great Resignation is a collective behaviour that is not only evident in a particular industry but contagious in multiple industries. With the reducing workforce, studies imply outputs have lessened resulting to a counterproductive and counter progressive operations (Harfoush, 2021 and Widodo et al., 2021). Reducing employee retention may have been recognized as a cost initially 'worth-bearing' but had eventually backfired as employers did not foresee the loss of their former employees, and the larger effect it had on the rest of their employees. As for the airline industry, the loss of long-term employees eventually costed the airline industry more due to immediate rehiring and training, poorer productivity levels, reduced quality and weaker company cultures (due to changes in workforce synergy).

As a result, the increased job resignation caused by job dissatisfaction and absence of employee retention led to decrease in productivity. However, the question whether employee retention was required and particularly at that point of a global economic and epidemic remains relevant. Considering the significance of this matter from an economic and a business practice point of view, the purpose of this study, therefore, is to explore how low-cost carriers (LCC) have retained employees and maintained job satisfaction in the post-pandemic workplace environment.

2. Methodology

2.1. Research Approach

The study is interpretive in nature for the purpose of offering better understanding of how different LCCs within the aviation industry were affected by the pandemic and respectively, how they responded to the challenging new environment. The study adopted a case study strategy as it enables an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple methods of data collection (Yin, 2018). This is intended for the study to offer a detailed picture of the examined phenomenon within the parameters of the studied organisations based on the perspective of their human resources managers and employees. Therefore, the study is based on examining two LCCs in different country contexts for the purposes of providing a better account for examination and comparison of the retention practices between them.

2.2. Sampling

A homogenous purposive sampling was adopted for the purposes of this study. The LCCs were selected from different geographical areas as that may increase the contrast/variations between the

LCCs' responses to the pandemic. The LCCs that have been selected to take part in the study operate under a parent company (airline-within-airline strategy) and that can potentially become a source of similarities between the carriers. From each LCCs, a HR manager and an employee were interviewed as this allowed information collected to be cross-checked/verified by the giver and receiver of HRM strategies.

2.3. Data Collection

The data collection relied on semi-structured interviews and secondary sources in the form of corporate reports, corporate websites and news reports. The interview protocol was developed on the basis of the research question and that allowed for rich information that would shed clarity on the research problem to be collected. The secondary data collection served for comparison and verification of the interview data.

2.4. Data Analysis

The data were analysed by applying thematic analysis and by coding the data. Upon completion of the interviews for the two cases - LCCa and LCCb, voice recordings were transcribed and then the initial stage of coding was initiated. Once all transcripts were initially coded, the codes were entered into a Microsoft Excel file to record how frequent certain codes would reappear. These were then sorted from most to least frequent, which was then manually reviewed. It is important to note that apart from the research question that guided coding, the research objectives provided a more meticulous approach that helped solidify what codes moved forward or not.

The codes were then transferred to another sheet wherein the codes were placed under relevant headings for each airline. After a series of coding, themes emerged from the chosen data sets that were then reviewed and refined until the themes were able to sufficiently answer the research question (through the perspective of the HR managers). The established codes and themes, however, were then reviewed and used as a foundation to develop the cabin crews' interview questions based on a few areas: (1) career development, (2) differences in productivity, (3) multiple work structures, (4) role of government (national authorities) and (5) recovery strategies. The cabin crews' interviews also went through thematic analysis. Corporate reports in the form of annual reports and Corporate Social Responsibility publications of both airlines (via website) were also referred to, to help gather secondary data that was used to compare and contrast the data collected from the respondents.

3. Key Findings

3.1. Introducing the Case Studies

LCCa is under its parent company which dominates the country's domestic market, outdoing the nation's legacy, former parastatal, full-service carrier (FSC). The airline operates from seven hubs with two local focus cities and serves 26 international destinations in 16 Asia-Pacific countries. LCCb on the other hand, shares a common ownership with one the country's full-service carrier (FSC). However, the management of Middle Eastern airline has been independent ever since. Though, LCCb is not under any airline alliance, it shares a codeshare agreement with associated FSC. LCCa accounts for 3.4% of the nation's GDP (US $2.7 billion) whereas LCCb partakes 13.3% of their GDP (US $19.3 billion). Both airlines in this study share the same largest market for passenger flow; to and from the Asia-Pacific region.

3.2. Comparing retention strategies between LCCa and LCCb

Responses from both airlines suggest that their means of retaining employees were reduced due to the pandemic. Both airlines have similar allowances, insurance and formerly promotions in their management structure. This suggests that LCCs despite geographical differences share similar structures in retaining their employees. Additions and modifications such as postponed promotions, implementation of furloughs, work from home and voluntary pay cuts were applied by both LCCs as a result of the pandemic. This may indicate that LCCs have responded to the pandemic in a similar manner regardless of their geographical.

3.3. Changes in retention strategies in LCCa and LCCb

LCCa and LCCb said that their retention strategies were "revised" and "were not necessarily adjusted to match the pandemic." Therefore, LCCs' adjustments to their retention strategies is a change in response to the pandemic as these were reactive rather than proactive measures. If the outbreak did not happen, pay cuts, furlough, work from home, reduced allowances and absence of bonuses would have been implemented. This is also reinforced and supported by the additional COVID-19 related training and newly introduced Standard Operating Procedures (SOPs) mentioned by the participants. Specific changes included the rescheduling of flights, COVID-19 related training, testing, quarantine, contact tracing, vaccinations and boosters, masks and avoidance of eating and drinking in-flight.

Cost limitations on retention strategies
Though there was a desire from both LCCs to provide means for retention as they recognize employees as assets, they simply could not allocate more of their financial resources to the retention of their valued employees. According to the participants, the carriers at peak of the pandemic were barely making ends meet with current cash flows and other strategic priorities outweighed their maximum efforts to retain employees.

Multiple work structures
When asked regarding multiple work structures, participants responded that this was a norm for this industry and is "essentially what has kept it going this far." According to the LCCb's HR manager, "the pandemic in a way has just intensified the differences [in structures]." This is because it has helped LCCs according to LCCa's HR manager to "deliver what was expected from them" and has "helped them remain productive." Data analysis showed that, multiple work structures were not as bothersome to begin with since its initial concept was not necessarily a new ground for aviation employees. Though there have been operational changes (increased work from home and furlough), the changes were not as drastic as in other industries. However, though furloughs, unpaid leaves, and Work from Home (WFH) structures that "amplified" the differences in work structures did not last long in LCCs' operations, these were said to impose an emotional or mental toll on its employees as changes were drastic.

3.4. Retention strategies on employee productivity and job satisfaction Absence of retention strategies and increased responsibilities of cabin crews

Based on data analysis results, the increased responsibilities at work that were not compensated by the airlines tested the resilience of employees. The crew emphasized in their interviews that though they are grateful to still have their jobs (knowing very well that their peers were laid off) there was pressure from management, an increase in difficult passengers, and enduring their colleagues' various ways to coping with change.

The respondents did not deny that the restructured operations were still "new" to them but were somehow always exposed to some kind of change as LCCs in nature, were prone to adjustments in their operations. However, these COVID-19 associated changes were said to be too rapid and extremely drastic. For instance, crew had to juggle anti-maskers onboard, pressure to not report positive (for the virus), and possible health risks that they may bring home. These were highlighted by LCCa wherein the airline suffered from never-ending revisions in protocol during the process of transitioning from 2020, to vaccine distributions, mutating variants, COVID-19 testing procedures, lockdowns and mandatory quarantines. In the midst of this, the LCCs were aware that there was only so much they could do for their crew in terms of career development and improving their response to change. According to the CSR reports from LCCa, 35% were laid off through a Voluntary Separation Program in July 2020 via retrenchment in August and October 2020. LCCb on the other hand, had 1,092 of 3,796 of its workers on an unpaid/voluntary leave.

Differences in job productivity

According to the respondents (HR managers and employees), both have recognized changes in themselves and their peers' productivity which was considered by the HR managers as "understandable" considering the challenges in terms of travelling for both passengers and cabin crew. Figure 1 outlines drivers for different employee productivity levels based on the data analysis.

Initial demotivation – Employees interviewed were initially "upset", "demotivated" and "discouraged" once the pandemic reached its global scale and operations had been revised to reflect the damage done by COVID-19 (i.e., change in SOPs and loss of colleagues). The crew during furloughs were anxious. At this phase, employees according to HR manager (LCCa) "still did what was expected" from them, but the "extra initiative that is usually there when they are comfortable" was affected – translating to reduced and compromised quality of productivity.

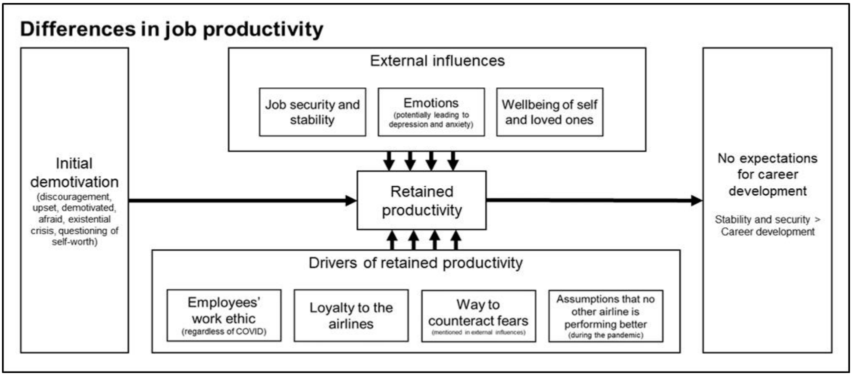

Figure 1: Drivers for different employee productivity levels.

However, a combination of factors (see Figure 1) may have resulted in a shift from reduced to improved or retained productivity:

- External influences – Upon the realization that employees were still fortunate to be working for the LCC at a time when people were struggling, factors such as (1) comparing their job security to that of former colleagues and terminated acquaintances and (2) reality of being (physically and financially) prepared to support themselves and their loved ones, stressed the importance of securing their job.

- Drivers of retained productivity – External influences may have further triggered employees' work ethic (i.e., "Not to mix my personal life with my work life"), loyalty to the LCC and assumption that no other airline is in a significantly better position. Upon weighing these factors, the crew may have used productivity to counteract their fears knowing that it has the potential to clear thoughts off their mind while also "prove the purpose/worth" to their employer – hitting two birds with one stone.
- As a result, employees are not necessarily expecting any form of career development (a type of retention strategy). A crew from LCCa stated that "it is the last thing on their mind." It was said that stability and job security that had become their core driver and for the time-being, their current source of job satisfaction.

Emotional impact and mental well-being of employee's during COVID-19

The cabin crew experienced various emotions ("upset", "demotivated", "discouraged", "afraid") that implied fear as an underlying factor. This resulted in questioning their self-worth ("existential crisis") and ability to contribute as employees and individuals as discussed in the previous subheading. Such behaviour implied possible concerns in mental health that may eventually lead to anxiety and depression. Upon going through CSR reports, LCCa has mentioned that they have arranged slots for psychological counselling of which 44 or 240 were availed in 2020. However, no information regarding this matter was published by LCCb nor mentioned by the interviewed HR manager.

The role of governments

Though the role of governments was vaguely touched on by LCCb, it was heavily emphasized by LCCa as it was mentioned numerous times in their interviews. This highlighted the direct impact of modifications to operations in a short span of time. The role of the government was primarily related to a couple of areas such as 1) Financial aid: LCCb received financial assistance from the local government which helped keep the airline industry on life support; 2) Changing protocols: In the case of LCCa, the instability of their SOPs affected not only the cabin crew but anyone that interacted with the LCCs' day-to-day operations. It resulted in demanding roles, unnecessary revisions and increased costs (masks, COVID-19 testing, quarantine sanitation) which in turn resulted in increased emotional frustration, stress and burnout.

Recovering from the pandemic

Findings suggest that both airlines wanted to simply stay afloat, cover its operating costs and continuously respond to the developments of COVID-19. This suggests that both airlines did not view employee retention as a core priority.

Communication within the LCCs

The pandemic tested LCCs ability to communicate changes (big or small) that eventually affected how employees dealt with and responded to changes. However, should there be a lack in the regulation of information passed around, employees may find it difficult to receive and verify information that is truthful – which may contribute to mental health.

4. Discussion and Conclusion

This comparative study aimed to explore employee retention strategies in the case of LCCs in a post-pandemic workplace environment. The study findings demonstrate that the LCCs' retention strategies have changed as a response to the severe impacts of COVID-19 on the airline industry.

Certain retention strategies had to be eliminated, reduced or temporarily pushed aside while COVID-19 associated SOPs were added with the guidance of governing bodies. The retention strategies were not as significant or "impactful" as they were pre COVID-19 as the challenging times of the pandemic have made job security and stability top priority. This suggests that though productivity levels may remain the same (if not higher) post COVID-19, job satisfaction may or may not be present within the workplace. In addition to this, the mental health of employees has reflected an unpleasant and stressed experience during COVID-19 that to an extent, has been subdued to protect their jobs.

Various internal and external factors that have not been previously discussed in the literature (e.g. Cigna, 2020 Kankaew et. al 2021; Harfoush 2021), were identified as important in the study as they played pronounced roles that affected the state of retention strategies and the limitations on LCCs in retaining valued assets, such as significance of job security and stability, employees' mental health, post -COVID-19 strategic priorities and the role of governments in a global crisis and recovery.

Job security and stability were the participants' biggest concern; as much as they were upset and discouraged with their situation, the fear of losing their stable income outweighed their feelings of demotivation. The fear of losing their purpose and finding themselves in similar challenging situations as their ex-colleagues, drove them to retain high levels of productivity despite the loss in motivation, a phenomenon that is observable in other non-aviation industries as well such as healthcare (Halcomb, et al., 2020; Deloitte, 2020).

This goes alongside the drive of most governments to stimulate their economic activities (Maneenop and Kotcharin, 2020). However, the governments of developing and developed countries are significantly different especially after the pandemic outbreak; arguably widening the gap of richer and poorer economies (Abate, et al., 2020; Levin, et al., 2022).

The strike of COVID-19 shocked the aviation industry at a time that was unlikely – wherein a disease outbreak of this intensity was thought to hit booming operations this drastically. The study advices LCC leaders to practice scenario-based thinking that account factors with similar natures to that of COVID-19 (unexpected, heavily impactful) that are naturally bound to occur again. At top level, historical data can be viewed differently and reanalysed alongside (during and post) pandemic figures to improve forecasting the feasibility of operations and the response strategies of airlines. LCCs may additionally also consider various degrees of cooperation and collaboration amongst other airlines (FSC and LCCs) such as interline agreements on testing new markets or merger/acquisitions with promising or "on par" competitors.

LCCs may also account for consumer changing expectations. Answering the question: "What secures a passenger to fly again?" In the case of LCCs, lower prices and convenient timings may no longer be the only criteria passengers consider for them to fly once more. Safety and health-related procedures may be an element that even price-sensitive passengers will be willing to pay for if it guarantees an overall safer flying experience.

Lastly, the study suggests LCCs to also re-evaluate employee retention strategies periodically if they still do not. Apart from restructuring the way they keep valued employees; their strategies must be able to prepare employees to become nimble. Investing in providing easily accessible mental health resources within the organization may improve employees' intrinsic motivators. The last two years have been difficult for both employees and employers. While aviation is bound to recover, the lessons taught by COVID-19 must drive airlines to optimize their new-found resilience to their utmost advantage – hopefully moving airlines to a much more sustainable and financially stable business model. It is only this way that the study believes that LCCs an better cope with changes without losing the people that make their operations a success.

The study relied on qualitative data only and for that reason its findings could be considered generalizable and transferable to the studied context only and to the concerned literature streams. Therefore, the study findings could be used to develop statistical instruments and tested in quantitative works. We recommend that scholars seeking to conduct further research may use a larger sample size to collect more insight in the same areas used in the study. Scholars may consider collecting insight from other LCCs to provide a broader comparison. Moreover, scholars may study two other countries from different continents to explore differences and similarities amongst them.

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Management of Change: Challenges in Managing Change

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Abstract The profound and multi-layered changes brought about by the COVID-19 pandemic resulted in unprecedented challenges for the aviation industry. The paper critically considers the effectiveness of the traditional Management of Change Risk Assessment (MOCSRA) relied on by management teams to mitigate the changes and associated risks brought about by the pandemic. Our analysis of the traditional MOCSRA illustrates that the traditional MOC concept and methodologies mainly implemented in the organizations operational areas were inadequate to manage the constant changes during the pandemic. Additionally, there is need to link the change of management processes taking place in boardrooms and by senior management with the traditional MOCSRA process which must evolve to capture the scope and extent of changes within the aviation industry.

Key Words *SMS, Risk Assessment, Change Management.*

1. Introduction

The aviation industry is a complex, rapidly changing and developing industry with a multitude of challenges. Capacity in 2019 climbed 3.4 percent, and the load factor rose 0.7 percentage point to a record high of 82.6 percent. The previous high was 81.9 percent set in 2018 (IATA, 2019). In 2020 1.8 billion passengers flew which was a decrease of 60.2% compared to the 4.5 billion passengers who flew in 2019 and a decreased in demand (measured in revenue passenger-kilometers, or RPKs) by 65.9%. International passenger demand decreased by 75.6% and domestic air passenger demand dropped by 48.8% compared to 2019. Total industry passenger revenues fell by 69% to $189 billion in 2020, and net losses were $126.4 billion in total (IATA, 2021). At the same time 2019 and early 2020 presented the industry with a number of challenges including the shooting down of Ukraine International Airlines Flight 75 on 8 January 2020 killing all 176 passengers and crew, the effects of the grounding of the Boeing 737 MAX, signs of a weakening global economy and increasing geo-political tensions. However, the biggest and unprecedented challenge that the aviation industry was faced with, was still to come. In March 2020 the World Health Organization declared the outbreak of the COVID-19 virus a pandemic (WHO, 2020), triggering the worst global health emergency and an unprecedented crisis never seen before in the aviation history with industry losses in 2020 at $137.7 billion compared to the losses in 2021 which were $42.1 billion (IATA, 2022).

The colossal scale of the outbreak and its impact on the aviation industry required an immediate executive response at the strategic, corporate, operational, financial, and many other levels of aviation activities to ensure an organizations survivability. The impact was so severe that many airlines ceased operations, a great number of aircraft had to be stored and parked, flying, cabin crew and other operational staff were laid off or sent on unpaid leave or even given early retirement, salaries were reduced, crew and operational staff lost their recency and medial certificates. Never before was there such a massive scale of change in all areas of activity in the aviation industry and the changes were unprecedented with regards to urgency, magnitude and impact. Change always comes with inherent financial, organizational, structural and safety risks. A review of major aviation crises during the last two decades clearly indicates that the aviation industry has dealt with crises in the past such as inter alia, the 2009 financial crisis, the volcanic ash eruption in April 2010 of the Icelandic volcano Eyjafjallajökull and even other health-related crises such as the outbreak of Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) (Sehl, 2020). Following in-depth analysis of previous crises and lessons learned, the International Civil Aviation Organization (ICAO), European Union Aviation Safety Agency (EASA), Federal Aviation Administration (FAA), International Air Transport Association (IATA) and other aviation organizations provided guidance material and a regulatory framework requirement in the form of ICAO Annex 19 Safety Management Systems (SMS), with the objective to support a proactive and even predictive safety management approach to enable airlines and other aviation organizations to be ready for the rapid changes impacting the aviation industry. As a result, operators and other aviation stakeholders slowly but surely started developing management of change safety risks assessments (MOCSRA) mainly related to areas of operations which were outlined in the ICAO, EASA, and IATA Operational Safety Audit (IOSA) guidance materials. However, the sudden and unprecedented COVID-19 crisis which resulted in such severe and drastic changes to normal aviation activities. Even though predictable, the aviation industry was unprepared and in a completely new sphere of operations which was impacted by sudden, and on some occasions, rushed and often conflicting governmental decisions. Fear of the unknown and tremendous media pressure were the main factors impacting governmental decisions and the aviation industry was vulnerable and completely unprepared for the unprecedented scale of an imminent global pandemic crisis.

The extraordinary COVID-19 virus that spread around the world caused an unprecedented aviation crisis with great uncertainties. The constantly changing governmental health requirements and procedures, the restrictions and the non-existing comparable medical data resulted in the decision to suspend all operations which was largely based on a rushed and unfounded risk assessment which produced a 5A result. The COVID-19 pandemic brought about a magnitude of continuous changes that were novel, rapidly developing, and which had to be simultaneously dealt with. For the first time in the history of modern aviation, organizations and their management teams had to address such a complex, highly evolving, hazardous period of change.

As we move into the post-pandemic era, our objective was to critically evaluate the aviation industry's readiness and the strategies employed in managing the crisis by considering the following questions: Whether the experience gained and the lessons learnt from previous crises adequately prepared the aviation industry to proactively manage a crisis of the magnitude of the COVID-19 pandemic. Was the industry ready through the safety risk assessment process to mitigate the severe risks and consequences brought about by a predictable and foreseeable pandemic? Was the traditional MOCSRA an effective tool to manage the unprecedented consequential changes which so greatly impacted the aviation industry?

The aviation industry relied on a relatively new concept, the Safety Management System and the element of Management of Change (MOC) to manage this unprecedented magnitude of change and the associated risks to the organization and its safety standards. The MOC risk assessment suddenly became the most significant organizational activity and the most powerful and effective tool for management teams to address the extent and level of change and to provide, in such a continuously changing environment, the key safety, operational, human, and even financial mitigating controls to reduce the safety, operational and financial risks to the organization.

In dealing with the COVID-19 crisis, the management of change concept, principles, and methodologies which were mainly being implemented in the organizations operational areas were inadequate for this magnitude of change and a new approach, with conceptual thinking and practical, effective, efficient, timely and controlled measures was needed. This pivotal moment of change in the aviation industry necessitated an in-depth review of the aviation organizations Management of Change process and methodologies. The impact that the COVID-19 pandemic had on the aviation industry raises a number of serious questions with regards to the way the industry had proactively prepared for the risk of a predictable pandemic. The industry had the time as well as the tools to prepare for a pandemic which is an identifiable hazard with profound risks. The question therefore is why regulatory and management levels, from international organizations all the way down to governmental authorities, civil aviation organizations, operators and stakeholders, were completely unprepared for a pandemic and failed to have proactively prepared mitigating controls and operational procedures to deal with this crisis.

2. Safety Management Systems – Management of Change

Aviation safety needs to be managed proactively by all stakeholders with an effective management of hazards and risks by implementing safety mitigating controls which are regularly evaluated, thus ensuring a systematic management of safety risks which undoubtedly enhances aviation safety and benefits the entire aviation industry and all its stakeholders. A Safety Management System provides aviation organizations with a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures by continuously improving safety performance through the identification of hazards, the collection and analysis of safety data and safety information, and the continuous assessment of safety risks (ICAO, 2018). It is a proactive measure to mitigate safety risks before they result in aviation accidents and incidents by defining the activities by which safety is managed in order to achieve levels of safety which are acceptable or tolerable. Annex 19 specifies the framework for the implementation and maintenance of a SMS which can be scaled and tailored to the organization and its activities. Irrespective of the size and complexity of the organization, all of the 4 pillars and 12 elements of the SMS framework should be applied (ICAO, 2018).

An essential element in the safety assurance pillar is the management of change which is defined in Document 9859 as “A formal process for systematic and proactive identification of hazards and of appropriate mitigation strategies and measures, to be applied to all changes concerning the safety of services provided by an aviation organization.”

2.1. Management of Change - The ICAO Doc 9859 Perspective

ICAO Safety Management Manual, Doc 9859, requires both States and operators to establish formal activities for the management of change under their operations and the 2018 4th edition has enhanced guidance on management of change in Chapters 8 and 9 for States and service providers, respectively. States and operators are required to evaluate and manage the impact of change in their aviation systems and their organizations and develop procedures to assess the impact of changes at a State and operational level. When changes are planned, the State and the operator should analyze the impact of the change on the existing system and, using the existing SMS process, analyze, assess and if appropriate mitigate any new or altered safety risks. No operation should take place in a changed system or operational context until all safety risks are evaluated. A management of change should focus on those changes that could have a significant impact on the State and operator’s ability to fulfil its legal obligations (process change) and on Safety Management System capabilities.

The fast developing and changing aviation industry undergoes continuous and endless changes which may be external or internal to the organization, however, when any change occurs, hazards may be introduced into an operation. A crucial part of a SMS therefore is that hazards are systematically and proactively identified, and that necessary and appropriate measures are taken to manage safety hazards and the consequential risks and that they are implemented and also evaluated. Any change can thus introduce new hazards which may impact the effectiveness of existing defences or result in new risks. When changes are introduced into a system, the established safety risk picture of the system will change. With regards to an operator, Doc 9859 specifically states that the SMS manual should include a detailed description of the service provider's policies, processes and procedures and that includes the management of change procedures (Doc 9859, at 9.3.8.3).

Examples of changes that can have a significant impact on the safety risks of an operator include organizational changes and operational change, such as, inter alia:

a) Expansion, downsizing, new type of operations, additional locations and operating bases and the impact on recourses, oversight and performance monitoring capabilities;
b) Changes in leadership and management personnel, crew retention. Changes in the management processes, including changes in methodology such as SRM and Safety and Quality systems, new management system structure;
c) Changes in the regulatory environment such as changes in existing National Aviation Authority policies, programs, and regulations; and
d) Changes in the operational environment, such as the introduction of new technologies, changes in infrastructure, equipment and services.

Communicating the changes is fundamental to the effectiveness of the management of change. It is essential that effected personnel within the State and affected service provider(s) are well aware of the change, its timing and impacts.

2.2. The Traditional Approach - SMS Management of Change

A formal management of change process should formally and proactively identify the changes within the organization which may affect the established processes, procedures, products and services and result in introducing new hazards. All necessary arrangements to ensure safety performance should be identified and described prior to implementing any changes. To do this, an effective SMS and risk assessment process is required. The result of this process is the reduction in the safety risks resulting from the changes to as low as reasonably practical level.

An analysis of the traditional 'Management of Change Safety Risk Assessment' (MOC SRA), clearly indicates that the unprecedented changes associated with the rapidly spreading COVID-19 virus imposed severe challenges and constraints in managing all the simultaneously occurring changes. The fact that all the changes were happening at the same time resulted in the MOC SRA process being identified as a crucial process that had to take place at board and senior management level as well having to expand its magnitude and scope beyond the normal operational activities of the organization. The MOC SRA suddenly became the critical tool and methodology to manage the constantly developing and evolving changes in aviation organizations and the industry. Managing the constant changes became the new normal of operations. How do we manage the challenges in a period of constant change and what are the new main elements required for the effective implementation of management of change process when everything is changing?

2.3. Transformational Change of SMS

Industries and organizations such as banking and aviation go through a developing life cycle depending on the respective industry and the organization's evolving needs which are also impacted by major financial, political, geo-strategical developments and changes and this may require having to undergo a transformational change consisting of radical and fundamental change that may arise from shifts in organizational structures, systems and organizational culture. This can be due to rapid changes in operational environment or imposed external factors and can be highly disruptive and stressful. Unplanned change often happens when there is a sudden and surprising event or condition imposed by external forces that requires prompt reaction by the organization, something which often leads to reacting in a disorganized manner (Khaw, et al, 2022). Remedial change is considered an urgent change that is aimed at providing remedies or solutions to current situations and existing problems and is therefore more urgent and visible (Glanz, et al, 2008). In dealing with the COVID-19 pandemic, aviation organizations had to implement transformational, unplanned and remedial changes all at once.

2.4. A Mindset Shift for SMS

The aviation industry changed at an unpredictably rapid pace and aviation managers across the industry grappled with unprecedented disruption resulting in a greater need for a change-ready culture. Change is constant, and safety leadership is a crucial requirement to establish a change-ready safety management culture. Safety leaders must guide senior management to shift the organization's perceptions of change management from an episodic solution to an ongoing organizational safety strategy that becomes an inherent part of the organization's DNA.

An operator's formal process for change management should take into account the following considerations:
a) Criticality: Here the operator is required to determine how critical the change is and in so doing must consider the impact on their organization's activities, the impact on other organizations and the aviation system as a whole. Criticality is closely related to safety risk.
b) Subject matter experts: Key members and experts in the aviation community, even from external organization, should be involved in the change management activities.
c) Availability of safety performance data and information: Past performance of critical systems is a valuable indicator of future performance and the operator should consider available data and information which can provide information on the situation and enable analysis of the change. Trend analyses in the safety assurance process should be used to follow safety performance measures over time and this should be considered when planning future activities under situations of change. In addition, it is crucial to take into account any deficiencies which may have been identified and corrected by previous audits, investigations or reports in order to assure the effectiveness of any corrective measures implemented.

The change management process includes the following 7 steps:

1. Understand and define the change by including a description of the change and why it is being implemented. Structure your changes by phases of disruption;
2. Understand and define who and what will be affect by the change, that may be individuals within the organization, other departments, external people or organizations or equipment, systems and processes. Changes might affect mitigating risk measures which are already in place and change can increase risks in areas that are not immediately obvious;

3. Identify hazards directly related to the change and carry out a safety risk assessment. It is also to review the impact on existing hazards and safety risk controls that may be affected by the change by using the organization's existing SRM processes;
4. Develop an action plan, define what is to be done, by whom and the time frame. Have a clear plan describing how the change will be implemented, who will be responsible for what actions and then schedule the tasks;
5. Focus on the issues with a direct impact on operational safety;
6. Sign off on the change. Confirm that the change is safe to implement. The individual with the overall responsibility and authority for implementing the change should sign the change plan; and
7. Assurance plan. Determine what follow-up action is needed and plan how the change will be communicated. Decide whether any additional activities such as audits, are needed during or after the change. Any assumptions made must be tested. (Doc 9859).

2.5. Change Management

The authors industry experience, academic and consultancy work during the pandemic provided in-depth insight of the severe challenges, risks and tremendously difficult dilemmas and decisions that had to be made in managing the crisis. Throughout the crisis, from the suspension of operations, initiation of repatriation flights, carriage of cargo in passenger cabin, resumption of domestic flights and then international flights under severe COVID-19 restrictions a number of MOC SRA were conducted. At the same time, the authors participated in implementing a number of change of management processes within organizations that were battling to ensure the survivability of their organization.

In the new constantly changing organizational and operational environment the MOC SRA process had to be implemented in all aspects and areas of performed changes within the organization. In the economic and geopolitical environment aviation organizations had to be ready to constantly revisit their daily operations, introduce new changes and identify hazards and risks to their operation. At the same time, they had to implement efficiencies to achieve and maintain a competitive advantage and minimize the impact of the externally imposed changes. This required top management's commitment to a strong 'Change Management' strategy which is strongly linked with the MOC SRA process. Change management concept is defined by Prosci, as "*the application of a structured process and set of tools for leading the people side of change to achieve a desired outcome*" (Prosci, 2022). The goal of change management is to help those impacted by the change make a successful transition enabling them to engage, adopt and use a change, given the change's requirements. Change management supports moving an organization from a current state (how things are done today, the normal operations, pre-pandemic) through a transition state to a desired future state (a state of continuous change) (Prosci, 2022). The Prosci 3-Phase Process provides a framework for achieving change at the organizational level. This organizational change management process requires change practitioners to work through three phases, namely, Phase 1, the Prepare Approach which is Change Management strategy and includes defining success, the impact of the change and the approach which includes assessing risk, identifying potential resistance, and establishing required roles; Phase 2, the Manage Change approach which is the Master Change Management Plan and includes planning and acting, tracking performance and adapting actions; and Phase 3, the Sustain Outcomes approach which includes review performance, activate sustainment and transfer knowledge (Prosci, 2022).

Change management is the new approach implemented by many organizations and this initiative affects the traditional MOC SRA which needs to be adapted to the change management organizational processes.

Leadership of change should thus communicate by building an effective safety message framework throughout the organization and ensure communication is clear, consistent and easily accessible to all. It is important for leaders and managers to explain the “why” behind new changes, followed by the “what” and “how” of their change management strategy. To be more effective, diverse methods for receiving and sharing safety information can be established to promote safety culture and compliance with operational standards and use can be made of livestreaming, video conferencing and collaboration software such as Teams, Zoom to stay connected with operational staff who may be working remotely. Engagement can be achieved by providing frequent transparent, timely and honest feedback. Leaders should ensure that they are consistently available to answer any questions and offer support when needed. Increased frequency of contact with operational staff to ensure all team members see their manager as a strong safety leader with engagement and collaboration behaviors and as a role model who leads by example.

Leaders of change also need to be adaptable, resilient and ambitious and inter alia, seek out safety data analysis and SPI/ SPTs and identify new patterns and safety concerns; remain objective in analyzing data and communicating results; resist comparing against normalized performance and reject the urge to “get back to normal” or compromise with a short-term “backup plan”; examine failures for what went wrong and determine they will be corrected; preserve a relentless commitment to the organization's safety culture mission and vision; acknowledge and reward staff that demonstrate excellence and commitment to safety; develop and promote safety advocacy; engage with operational staff motivating them to remain focus on safety during this uncertain period; mobilize their team around what opportunities the disruptive environment can bring; urge operational crew to strive for excellence; address the human and physiological factors of change; and obtain additional expert support if needed.

2.6. Consequential Hazards and Risks

The suspension of operations due to the COVID-19 pandemic by many airlines, the transition to a period of performing repatriation flights during the start of the pandemic and the sudden change in government policies to permit limited resumption of operations under strict guidance are among the most profound changes the industry had to deal with at the start of the pandemic. Aircraft were put into maintenance parking and storage, a process never before implemented by many airlines, and as a result, the return of the aircraft back to normal operations created new hazards and risks. Since the beginning of 2020, Airbus received an increasing number of unreliable airspeed events which were mainly associated with obstructed pitot tubes after aircraft were in storage or parked for a long period of time. In the 2021 edition of Airbus’ safety-first Magazine, a number of articles were published highlighting the risks associated with the incorrect implementation of maintenance storage procedures (Airbus, 2021).

During the same period ICAO, and subsequently many National Aviation Authorities, published guidelines for the renewal of flight and cabin crew licensing recency requirements when access to simulators training facilities were restricted. The way that operators dealt with this drastic change through effective MOC SRA ensured the safety of their operations. EASA’s Return to Normal Operations safety risks management guidance were extremely helpful, demonstrated leadership and provided much needed support to many operators which ensured a relatively smooth but safe return to operational status.

As we return to the pre-pandemic operational environment there are a number of key activities that are impacted by the continuous changes in the organization. There are tremendous financial pressures on all aviation stakeholders to return to profitability and minimize losses and this pressure resulted in extensive efforts to cut costs, maintain a highly demanding schedule program, and add new aircraft and routes while manpower or training levels have not returned to the required levels. Organizations that implemented major changes in a quick, rushed manner based on fundamentally faulty assumptions regarding critical numbers or processes will face new operational and safety challenges that need to be captured by an enhanced MOC SRA process. In addition, the effective management of change which is critically related to a transparent and a highly efficient communication policy should also be included in a new and enhanced MOC SRA process.

3. Conclusion

In today's complex, uncertain economic, geopolitical and health environment, aviation regulators and organizations must establish a new enhanced approach to manage the constant changes in order to survive and maintain their operational and safety standards. In the aviation industry's current cut-throw competitive environment, organizations must constantly examine their processes and performance strategies to better understand what changes need to be made and link those changes to an enhanced MOC SRA process throughout the organization.

The new MOC SRA must be able to adapt and adjust to any rapidly developing change. Constant change must be accepted as the new reality in aviation and resistance to the change not only risks losing a competitive advantage but more importantly, it may lead to an increase in safety incidents and operational inefficiencies that will undoubtedly impact the organization's reputation. The ability therefore to manage change effectively is of critical importance and the MOC SRA element of the SMS, as a result of changes that have occurred during the last few years, plays a fundamental and critical role in the effective implementation of the SMS throughout the organization, starting from the board room. Organizations that fail to link the change management and the MOC SRA process and fail to implement the necessary mitigating controls do so at their own risk.

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The Relationship between Perceived Safety and Customer Satisfaction with Commercial Airlines

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Abstract The main purpose of the study is to determine how passengers' perceptions of safety is linked to customers overall satisfaction with the commercial airlines. In order to examine consumers' satisfaction with airline services; demographic characteristics, and service quality metrics are examined. A structured questionnaire of 313 passengers flying commercially on a full-service airline was used to conduct the research. Customers' impressions of airline service quality are evaluated using SERVQUAL's perception scale. An airline-specific adaptation of the performance criteria has been developed here. This study research included two extra aspects in conjunction to SERVQUAL's five aspects (reliability, responsiveness, assurance, empathy, and tangibles). There was a strong correlation between passengers' overall satisfaction and their perception of safety.

Key Words *Consumer Satisfaction, Safety, SERVQUAL Scale, Commercial Airlines.*

1. Introduction

Globally, the airline industry plays an essential role in developing economies. According to Chen et al (2015) airline industry entails transporting goods and passengers from one place to another. The airline services are in different categories, depending on operations like charter flights. A study on the connection between perceived safety and customer satisfaction is a topic that attracts heated debate from scholars and practitioners because of its impact on the competitiveness and profitability of commercial airlines. Perceived safety lacks holistic quality measurements; thus, it is measured from customers' perceptions. The value of perceived safety is inherently subjective. Hapsari et al (2016) customers evaluate perceived safety by differentiating assumptions using the SERVQUAL model. The model comprises five dimensions tangible, empathy, responsiveness, reliability, and assurance. Reliability defines the capacity of a firm to achieve the pledged services accurately and unfailingly. Responsiveness refers to the preparedness to provide fast services. Assurance represents employees' knowledge and courtesy to ensure that customers are convinced that the organization will meet their expectations. Tangible is the physical portrayal of services. Empathy relates to a situation where employees must understand and show attention to the customers.

Customer satisfaction in commercial airlines is associated with service quality; hence, a firm needs to sustain customer satisfaction by offering perceived safety. An increase in the quality of the services provided in the organization increases perceived safety and, in the long-run, customer service satisfaction (Nunkoo et al., 2017). The research paper will evaluate the relationships between perceived safety and customer satisfaction with commercial airlines.

1.1. Background and Statement of the Problem

Perceived safety in commercial airlines is difficult to measure as the services in the industry are executed concurrently, and delivery means the involvement of many entities like airport authorities and service providers. For customers to get safety during their travel, there is a need for a unified effort that aids in the coordination of various procedures required in delivering qualities services. According to Hussain (2016) a relationship exists between perceived safety and customer satisfaction in commercial airlines. According to Kusumawati and Sri Rahayu (2020) perceived safety and customer satisfaction are integral and contradictory constructs.

Customer satisfaction significantly impacts customer loyalty and shareholder value (Oliver 1999). The importance of customer contentment in achieving various corporate goals cannot be overstated. In this highly service-oriented business, determining significant drivers to improve customer satisfaction necessitates an understanding, and knowledge of its major antecedents from the perspective of the consumer. Researchers Anderson, Pearo, and Widener (2008) found a crucial discovery: client satisfaction with core business aspects and peripheral service aspects is related to their total satisfaction. Satisfaction with the flight and on-time arrival are two critical components in providing excellent customer service. Other service aspects include passengers' comfort with the aircraft, the food provided, personal space in the aircraft, and encounters with airline workers; all of which are considered peripheral service elements. Moreover, the authors point out that there is no single aspect that adds to overall consumer satisfaction. Instead, the effect of driving constructs on satisfaction of customers is moderated by individual passenger factors (such as sexual identity, age, wealth, the number of journeys taken in a certain period, and the scheduled travel class). Safety is not a factor in Anderson's, Pearo's and Widener's (2008) model of total satisfaction. Surprised by this model's lack of safety concerns, Atalik and zel (2007) found that in the viewpoint of aircraft passengers, safety is an important consideration. As a result, customers' perceptions of risk have been shown to have a negative impact on their overall satisfaction. There has been a noticeable decrease of passengers since the events of September 11, 2001, which shows that consumer perceptions of risk do influence their travel choices. Therefore; perceived safety can be presumed to impact customer satisfaction in commercial airlines.

2. Literature Review and Hypotheses Development

2.1. Service Quality

A company's performance and ability to acquire some competitive advantage depends heavily on the quality of its services. It is particularly linked to corporate profitability as a result of repeat client loyalty and market share growth as a result of customer satisfaction (Oh and Kim, 2017). As a result of its significant effects, it has gained a lot of recognition in the service marketing literature and thus is widely debated by numerous scholars. Moreover, Service Quality is widely acknowledged as a significant factor in client satisfaction and loyalty (Oh and Kim, 2017, pp7). This chain association, which improves service quality, helps to improve customer satisfaction, and consumer contentment resulting in customer loyalty, is well-known. In addition, this association has been empirically supported in the aviation environment by various academics. Despite this, it is challenging to define and quantify service quality due to its inherent intangibility. Liou et al. (2011) argue that there is not one uniform concept of quality of service. Service quality perception is said to be context-dependent, and as such, researchers suggest that it should be measured considering the operational conditions under consideration.

SERVQUAL model was integrated into measuring perceived safety. The model is a measure integrated into deducing and identifying customer perceptions and expectations in terms of safety. The model is reliable and accurate in assessing perceived safety and quality in various industries (Oh & Kim, 2017, pp7). The method integrates five dimensions in addressing the differences in customers' perception of the services offered by different commercial airlines. The study incorporated the model to determine the relationship between perception of safety and customer satisfaction in commercial airlines. Some scholars have criticized the SERVQUAL model, but some have documented its effectiveness and application. In this study, SERVQUAL dimensions are essential and multifaceted elements.

2.2. Perceived Safety

Travelling on air poses many threats to passengers. Some of the risks involved are social, psychological, and financial risks. Even if the airline industry promises its customers safety, it is prone to physical threats. The occurrence of accidents cannot be prevented entirely, and all customers are conscious of this reality. Most customers regard air travel to be the most than assumed from an objective viewpoint because people overrate the threats connected with low-probability events (Nunkoo et al., 2017). The media covers airline catastrophes, making the public aware of various events. Therefore, perceived risks play a crucial role when evaluating consumer behavior in the travel industry. Perceived risks refer to the subjective anticipations of losses. For customers, consumer perception of safety is a personal factor.

Customers are known to adjust service assessments to past expectations in order to minimize the cognitive conflict generated by wide discrepancies between a priori expectations and ex-post evaluations. As a result, lesser expectations lead to poorer satisfaction levels as compared to a more risk-averse buy. Airlines employ a variety of safety and security procedures to reduce the dangers involved with flying. The fact that customers know of the broad measures needed to ensure air travel is safe does not mean that they are able to accurately estimate the level of safety. To get a sense of how safe an airline is, they use proxy metrics like the quality of the airline's service or the intensity of airport security checks to make judgments about a flight's safety (Han and Hwang, 2017). As a result, these interactions have a significant impact on how passengers view their own safety. It has been argued that security checks are a nuisance to passengers, increasing wait times and decreasing customer satisfaction, but we believe that the benefits of a sense of security outweigh any potential downsides. Customers are more likely to be satisfied if safety precautions are in place.

2.3. Customer Satisfaction

Regarding the quality of services and products, business performance plays an essential role in customer satisfaction. Customer satisfaction is conceptualized into cumulative and transaction-specific. Transaction-specific satisfaction links with a service or product experience, whereas cumulative satisfaction, is the entire assessment of the experience of the process. Customer satisfaction refers to meeting the expectations and needs to improve value creation. According to Moon et al. (2017, pp750) customer satisfaction is related to customers' attitude towards products and services- the degree to which they like or hate services they encounter. Customer satisfaction is a state of mind and entails the process and results of the consumption experience. Customer expectation is a modified appraisal between needs and expectations and delivered services. To comprehend how customers, make purchases and how businesses can achieve long-term profitability, the marketing literature considers customer satisfaction as a key component. Customers' reactions to their purchases, after they have had a chance to use the product, are what we call "satisfaction." In determining whether they are satisfied or dissatisfied with their purchases, consumers blend their feelings with their knowledge of product qualities. Client evaluation results in three outcomes: (a) neutral attitudes when the services are standard, (b) satisfaction when services are above standard level, and (c) discontent when productivity is regarded worse than standard.

2.4. Perceived Safety and Customer Satisfaction in relation to service quality

The literature on marketing is divided on the issue of whether consumer satisfaction and perceived safety is impacted by service quality parameters. Client satisfaction is often believed to be impacted by service provided. However, several studies (Bitner, 1990; Bolton and Drew, 1991, Oliver, 1997) have shown that the satisfaction of customers with a certain service experience leads to a general perception of service quality. Study after study has shown that user satisfaction is significantly associated with the perceived quality of service in the commercial airline service industry; and this is consistent with the previous paradigm. Research into the link connecting inflight service quality and client contentment is lacking in the airline context. Airlines, on the other hand, go to great lengths to give their clients high-quality goods and services in order to win their loyalty and business in the future. Traveler satisfaction is directly influenced by the quality of in-flight services, according to Etemad-Sajadisss et al. (2015). A study on Korean travelers researched by An and Noh (2009) indicated that service quality, encompassing assurance, responsiveness, reliability and empathy as well as food delivery, affects consumers' satisfaction by the class level they are flying. Customer satisfaction has been shown to be positively affected by both service quality and pricing according to a study done by Calisir et al. (2016). It was shown that client satisfaction and loyalty in Ugandan airlines were influenced by the level of pre-, in-, and post-flight service quality. All services left a considerable impact on customer satisfaction, according to the study. El-deen, Hasan, and Nancy also found a substantial association between in-flight amenities and consumer satisfaction (2016). The quality of the crew, the food, the new fleet, and the enhanced in-flight amenities all impacted the consumer satisfaction.

Consumer satisfaction in commercial airlines is associated with service quality; hence, a firm needs to sustain customer satisfaction by offering perceived safety. An increase in the quality of the services provided in the organization increases perceived safety and, in the long-run, customer service satisfaction (Nunkoo et al., 2017).

2.5. The Relationship between Perceived Safety and Customer Satisfaction

Customer satisfaction and perception of safety are distinctive and complementary concepts. Today, most organizations prioritize their customers' safety and ensure they receive quality services. Quality of service in an organization is a multifaceted and ephemeral construct that determines customers' safety, satisfaction, and dissatisfaction. Safety is not the only component regulating the level of satisfaction among airline passengers (Chen et al., 2015).

The primary view is that perception of safety precedes customer satisfaction. Customers must experience the service of commercial airlines to determine whether they are satisfied with the encounter they had in terms of how they perceive their safety during the flights (Hapsari et al., 2016). Perception of safety is more holistic and is established over a long duration, whereas customer satisfaction refers to a specific encounter. Perceived safety has more cognitive content, whereas customer satisfaction focuses on the impacts of the experience. The evidence of the connection between perception of safety and consumer satisfaction is unsettled.

Flights are predicted to climb by 5% each year over the next two decades, which means the demand for airline safety systems will expand along with it (Russell-Bennett et al., 2007, n.p). Perceived safety measures how secure people believe they are. It also alludes to the fact that one is completely protected from any kind of harm, injury, or danger. As an alternative, some academics have defined perceived risk as an opportunity to experience the negative consequences of a loss and to experience sensations of anxiety, uneasiness, and discomfort. Purchase and travel on an airline carry a variety of dangers, including psychological, financial and social risks. When it comes to evaluating and making a purchase choice, understanding the customer's perspective on risk is critical. As a result, buyers are more concerned with avoiding a mistake than they are with maximizing the value of a purchase. Deciding is a complex process that involves weighing the costs and benefits of several options (Russell-Bennett et al., 2007, n.p). satisfaction is positively correlated with aircraft safety, according to several research studies. In line with the above discussions, the hypotheses below are proposed:

> ***H1:*** The perceived safety of an airline has a positive impact on the consumer satisfaction.
> ***H2:*** Customer satisfaction is significantly impacted by perceived safety.

2.6. Data Collection Methods and Instruments

The study integrated a self-administered questionnaire as a tool for gathering data. Questionnaires were used to ensure high levels of uniformity and anonymity. The questionnaires were structured in an easy way that all the respondents could understand. The questionnaires were distributed before the flight departure and covered the airline's safety and quality of services. Aircraft stewards gave a brief statement about the poll throughout the flight and addressed travelers who volunteered to partake the survey. Respondents were provided with enough time to answer the questionnaire in a comfortable setting.

2.7. Study Population

The target population of the research comprises domestic air passengers. The study incorporated the stratified multi-stage sampling approach. The first step involved classifying flights schedules into three classes: morning, afternoon, and evening flights. The survey included morning flights as they had the highest flight traffic. A total of 379,015 travelers were included in this investigation. A total of 363 of the 400 questionnaires distributed were retrieved as complete in this study. Another 50 submissions were discarded due to the lack of prior knowledge about the commercial airline's services among these passengers. A sum of 313 valid questionnaires were then gathered, with a response rate of 78.25%. Statistical software was utilized to evaluate quantitative information (SPSS, version 25.0).

3. Measure

3.1. Quality of in-flight service

Customers' impressions of airline service quality are evaluated using SERVQUAL's perception scale. Where the evaluation criteria have been altered to better suit the needs of an airline. This research has two new aspects in conjunction with SERVQUAL's five aspects: reliability, responsiveness, assurance, empathy and tangibles. Food and entertainment are the two new components because these aspects are usually seen as intertwined components of overall in-flight service quality therefore our research included them.

3.2. Perceived safety

Responses to a single item were used to gauge how safe travelers thought the airline was. There have been other studies that have employed this measurement scale, however they all used a different set of elements or dimensions instead.

3.3. Customer satisfaction

Customer satisfaction was assessed using four different metrics. Of these, overall service quality and validation of expectations are among the most important aspects of the airline's performance. Alpha dependability is 0.86 on the scale. With the exception of questions concerning demographic characteristics, all measurement items were graded using a Likert scale with seven points, spanning from "strongly agree" to "strongly disagree" from (1) to (7); in the questionnaires which were distributed. Appendix A lists the variables that will be examined.

Scale	**Cronbach's Alpha**	**No. of items**
Inflight service quality		
Food	0.901	4
Entertainment	0.917	3
Reliability	0.825	5
Responsiveness	0.867	4
Assurance	0.882	4
Empathy	0.891	5
Tangibles	0.850	4
Perceived Safety * 1		
Satisfaction	0.855	4

Table 1: Reliability Statistics. * is the perceived safety which is determined by a single item scale.

4. Data analysis results

4.1. The Demographic Elements

Overwhelmingly, 80% of those polled have either a university degree or a high school diploma of some kind. This statistic shows that majority of the travellers are literate. Only 26% of respondents reported flying with this airline on a regular basis; 57% were male customers between the ages of 36 and 45; 49% had a yearly salary of $20,000 and $39,999; and 54% indicated flying with commercial airlines once or more in the past year.

4.2. Descriptive statistics and Pearson Correlations

The descriptive data suggest that the 'responsiveness' component got the greatest overall mean (5.97), whereas entertainment score was (3.81), satisfaction score was (5.36) and tangibles (5.32) scored the poorest. Airline flight service quality can be improved further, according to these findings. It appears that travelers believe this airline to be safe based on the average rating of 5.81. Considering these facts, customers will continue to fly with the airline. They are, however, dissatisfied with the level of service provided on board. Correlation analyses among seven variables of service quality namely; responsiveness, reliability, empathy, tangibles, assurance, food and entertainment, were first undertaken prior to conducting the regression analysis. Perceived safety and customer loyalty were found to be correlated with each of the seven dimensions. As previously noted, the correlations between these variables were examined using a correlational approach. The correlation findings suggest positive and statistically significant associations in all dimensions.

This study found an upward link between service quality and perceived safety, which leads to increased client satisfaction. Despite the strong association between service quality and client satisfaction, the client's viewpoint may differ. A direct link between the two cannot be shown, hence it is impossible to prove (Howell, 2007, n.p). Using multiple regression analysis, statistical correlations were predicted between these variables, namely; perceived safety, customer satisfaction, and service quality.

5. Hypotheses Testing

5.1. Testing hypothesis one: the service quality significantly impacts perceived safety and consumer satisfaction

Predictor	**Satisfaction Coefficient**		
	Model 1		
	Beta (B)	t-value	p-value
In- flight service quality			
Food	0.09*	1.93	0.05
entertainment	0.18*	4.45	0.00
Reliability	0.20*	3.35	0.00
Responsiveness	-0.01	-0.09	0.93
Assurance	0.03	0.47	0.64
Empathy	0.24*	3.52	0.00
Tangible	0.28*	6.37	0.00
Satisfaction			
df (7,305)			
In-flight service quality F= 104.41 R2= 0.71 (Satisfaction)			
Indicators: tangibles, empathy, assurance, responsiveness, reliability, entertainment, food Dependent variables: Consumer satisfaction (Model 1) Note: *p <0.05.			

Table 2: Consumer satisfaction and service quality regression analysis.

Customer satisfaction and quality of in-flight service were examined as part of hypothesis one's testing process. In order to determine how much of the dependent variable's variance might be explained by each of the seven dimensions, they were included in the regression equation. Table 4.0 – (Model 1) depicts that 71% of the variance in client satisfaction can be analyzed using the seven characteristics of service quality, with an R2 of 0.71, F (7, 305) = 104.41 and a P-value of 0.05. These numbers show that the regression model produced a statistically meaningful outcome. Hypothesis one is confirmed considering this finding. Client satisfaction is directly correlated to the service quality of commercial airlines. Customer satisfaction was found to be significantly influenced by five different aspects of in-flight service quality, as shown by the coefficient table.

5.2. Testing hypothesis two and three

H1: *The perceived safety of an airline has a positive impact on the consumer satisfaction.*
H2: *Customer satisfaction is significantly impacted by perceived safety*

Predictor	**Satisfaction Coefficient**		
	Model 1		
	Beta (b)	t-value	p-value
Constant		7.724	<0.001
Perceived Safety	0.59	13.043	<0.001
df (7,305) F= 170.11 R2= 0.35 (Model 1)			

Table 3: Regression analysis of the connection between perceived safety and consumer satisfaction. Predictor: (Constant) Perceived Safety. Dependent Variables: Consumer Satisfaction (Model 1), Note: *p<0.05.

The link between customer satisfaction and perceived safety is depicted in Table 5.0 (Model 1). According to the model, client satisfaction is well predicted by perceptions of safety (T value = 13.043, R2 = 0.35, and F value= 170.113), therefore the regression is statistically meaningful (p <0.001). Perceived safety accounts for 35% of the variance in customer satisfaction in this study's regression model. The independent variable is shown to have a statistically remarkable effect on client satisfaction (p-value <0.001). Using the beta coefficients (0.59), the perceived safety is a good determinant and has a favourable impact on consumer satisfaction.

6. Discussion

The study investigated the relationships between client satisfaction and their perceptions of service quality in terms of tangibles, empathy, assurance, responsiveness, reliability, entertainment, and food.

For hypothesis 1, the results suggest that consumer satisfaction was significantly influenced by the quality of the in-flight services. The quality of in-flight services predicts 71 % of passenger satisfaction. Food and entertainment were regarded as the least influential aspects amongst service quality components, whereas tangibles, empathy, and reliability had the greatest impact on satisfaction. Unlike earlier research on airline service quality, this study found assurance and responsiveness to be insignificant factors. When it comes to analyzing the parameters, assurance refers to the flight crew's competence and courtesy, as well as their capacity to build trust, whilst responsiveness refers to the cabin crew's ability to respond quickly to customers' requirements. Even though these attributes are key components of the flight crew's service abilities, they are not regarded as extremely crucial variables in determining customer satisfaction. There are two possibilities for this. For starters, cabin crews' customer-service skills are taken for granted, and clients anticipate premium airline standards. Second, travelers who are used to flying have a lower threshold for criticism and are less demanding (Archana and Subha,2012). They may understand cabin workers' responsibilities include doing several jobs in a short amount of time. In this way, the influence of these two aspects on satisfaction is minor. Respondents, on the other hand, said that enhancements in food service, entertainment systems, cabin items, and flight attendant service would make them feel good.

In terms of hypothesis 2 and 3, it was discovered that perceived safety appears to be a significant driver of customer satisfaction. Per the key findings, the perception of aviation safety has a considerable and negative impact on client satisfaction. This is in line with Ringle et al. (2011) preliminary findings, which found that safety perception was an important determinant of satisfaction and a statistically significant factor in predicting loyalty. There are two plausible explanations for these observations. First and foremost, perceived safety is an operational aspect of aviation services. It is regarded as a critical performance criterion that underpins airline operations and must be met to the greatest possible standard. As a result, its poor performance will cause dissatisfaction. Second, because safety is so important, consumers tend to prioritize it in their decision-making processes when choosing an airline. Chang and Hung (2013) confirmed this viewpoint in their study, which found that perceived safety is a factor in customer satisfaction with cheap airlines. As a result, as customers' perceptions of safety increase, their chances of being satisfied with airline service and, as a result, loyalty will increase.

7. Conclusion

The study focused on exploring the relationships between consumer satisfaction, perceived safety, and service quality in commercial airlines A major goal of the study was to discover the most important quality criterion in the in-flight service that causes consumer delight and subsequently influences their satisfaction. We also added the "in-flight service quality – satisfaction" paradigm into our research model to improve customer perception. This provides a different perspective on how passengers perceive the service. Until recently, there have been no studies that have looked at these correlations in this manner. According to our results, there are five key aspects of service quality that contribute to customer satisfaction. Service quality and client perceptions of safety have a major influence on passenger satisfaction, according to our findings. As a result, consumer loyalty is influenced by how satisfied customers are with their travel experience.

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The Impacts of Climate Change on Aircraft Noise Near Airports

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Abstract This paper presents the impacts of climate change on aircraft noise at Chios Airport in Greece. Departure noise contours are generated using the IMPACT assessment tool for the A320 and B737-800 aircraft. Since 1974, observed climate data shows that the average minimum temperature has increased by 0.75°C per decade and the average windspeed has decreased by 2.26 knots per decade. Since 1997, the degraded take-off performance has expanded the 60dB L_{den} noise contour area by up to 4.8%, increasing the population exposure to aircraft noise. Further research about the local climate impact on aircraft noise at busier airports is recommended.

Key Words *Aircraft Noise, Climate Change, Airports, Environment.*

1. Introduction

This paper provides details of the first known study on how climate change has had an impact on aircraft noise close to an airport. Chios Airport in Greece is used as a focus of the study as local historical climate data show that the airport has experienced both an increase in temperatures and a decrease in wind speed since 1974 (Gratton et al. 2020). Both temperature and wind speed are known to impact aircraft performance and vertical trajectories and therefore impact the level of noise experienced by communities living close to the airport. Two short-haul, narrow body jet aircraft, the Airbus A320-232 and Boeing 737-800 are capable of operations at Chios Airport and are used in this study to assess their noise impact.

Since the 1950's, improvements in aircraft and engine technology have significantly reduced the environmental impact of flights. However, in that time, the number of flights has increased dramatically and continues to do so (Lee et al. 2001). The International Air Transport Association (IATA) forecasts, even despite the interruption caused by Covid-19, that over the next two decades, passenger numbers will grow at an annual compound growth rate of 3.7%, doubling the number of passengers from current levels (IATA, 2020). Aviation's contribution to noise and air pollution and long-term climatic variations through the release of greenhouse gases is now widely accepted. Aircraft noise and its impact on communities living close to airports is a major environmental issue. While aircraft have become quieter and cleaner in the last few decades, environmental concerns continue to slow down European airport expansion and EASA (2019) suggests that 60% of the 100 busiest airports in Europe now apply an environmental charge to aircraft operators. In 2012, the European Commission formed the Noise Expert Group which has enabled 'detailed discussions with Member States and stakeholders on environmental noise policy issues.

The issue of aircraft noise is more than just a nuisance to residents. Several published studies have indicated that noise pollution has contributed to a reduced quality of life, poor health and a subsequent increase in the risk of medical conditions. Stansfeld et al. (2005) studied 2,844 children exposed to aircraft noise across three European countries. They concluded that noise from aircraft could impair cognitive development in children, specifically reading comprehension. Hansell et al. (2013) showed statistical evidence that high levels of aircraft noise were associated with increased risks of stroke, coronary heart disease and cardiovascular disease for both hospital admissions and mortality near Heathrow Airport in London. The societal impacts of aircraft noise has led aircraft and engine manufacturers to develop more quieter aircraft and the rate of progress has been rapid. For example, ICAO (2010) highlighted that aircraft then were 15% more fuel-efficient than a decade previous and that noise levels had reduced by more than 90% since jet aircraft were introduced in the 1950s.

In addition to the negative environmental impact of aircraft noise, the aviation industry is also a major contributor to climate change due to various direct and indirect sources of greenhouse gas emissions. The contribution of the industry to climate change has been widely studied over the last few decades. However, recent research studies (Burbidge, 2018; Thompson, 2016) have also highlighted that the aviation industry will need to adapt to the consequences of climate change. Many of the known impacts of climate change on aviation are provided in a review by Ryley et al. (2020). For example, some studies have shown that higher temperatures impact aircraft take-off performance due to increasing take-off distances (Gratton et al. 2020; Coffel et al. 2017). This has a commercial impact on aircraft operators due to the requirement to offload weight, usually payload. In another example, Williams (2017) suggests that the prevalence of clear-air turbulence will increase as the climate changes. This represents a potential increase in safety-related incidents in the future. The purpose of this paper is to build on existing research into the how the changing climate impacts the aviation industry. This study presents results for Chios Airport in Greece showing the changes in aircraft noise exposure for communities living close to the airport since 1974 due to changes in the local climate.

2. Methodology

2.1. IMPACT Noise Assessment Model

Prior to the development of any new or existing airport, there is often a requirement to conduct an environmental impact assessment study. As a result, a number of models and tools have been developed which estimate aircraft noise and emissions at and close to airports. This study makes use of the IMPACT model (version 3.36) developed and maintained by EUROCONTROL which can quantify noise and emissions for a range of commercial aircraft. The IMPACT model is approved for conducting assessments for the Modelling and Database Group (MDG) of the ICAO Committee on Aviation Environmental Protection (CAEP). The model is also compliant with the European Civil Aviation Conference, ECAC Doc 29 detailing the standard method of computing noise contours around civil airports. The model makes use of user-input data such as airport, runway, aircraft type and operator procedure information to construct a vertical, lateral and temporal trajectory of the aircraft for various phases of flight such as departure, climb, cruise, descent and approach. The 4D aircraft trajectory is determined using the Base of Aircraft Data (BADA) aircraft performance model (version 4.2) developed and maintained by EUROCONTROL. The BADA model assumes an aircraft as a point and equates the rate of work done by forces acting on the aircraft to the rate of change in potential and kinetic energy. The propulsive force is used to determine the mass fuel burn and emissions. Further details of the BADA model and an overview of the modelling approach is provided in Nuic et al. (2010). Once a 4D flight trajectory is determined, the Noise Calculation Module (NCM) within IMPACT uses the Aircraft Noise and Performance (ANP) Database (version 2.2) to calculate aircraft noise indices and generates noise contour maps around the airport. Only aircraft noise is simulated, and any background noise from other sources does not contribute to the noise contours. Further details of the IMPACT noise and emissions model is provided in EUROCONTROL (2020). The vertical atmospheric conditions within IMPACT are based on the variations in the International Standard Atmosphere (ISA). The atmospheric parameters at the airport are set by the user for temperature, pressure, relative humidity and headwind component (being the component of total wind resolved parallel with the take-off runway, assuming that an aircraft will always elect to take off into the prevailing wind, or at worst with a 90° crosswind, which would be zero headwind). For the purpose of this study, the relative humidity was set at a model default value of 76.5% for all cases.

2.2. Chios Airport and Local Climate Data

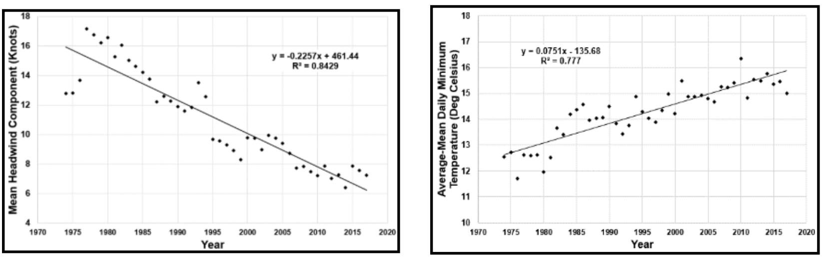
The study was conducted for Chios Airport, on the island of Chios in Greece. Information about the airport including the declared runway distances and the elevations were taken from the Aeronautical Information Services (AIS) documents published by the Hellenic Civil Aviation Authority. A summary of the airport data is provided in Table 1.

Airport ICAO/IATA Code	**LGHI/JKH**
Airport Elevation (metres above mean sea-level)	4.42
Runway Numbers	01/19
Runway Length (m)	1511
Runway Alignment	006°
Runway Slope	0°
Runway 01 Threshold Location	38° 20' 16" N 26° 08' 22" E
Runway 19 Threshold Location	38° 20' 56" N 26° 08' 30" E

Table 1: Chios Airport Data.

Climate data for the airport was determined from historical records from the period 1974 to 2017. The data consisted of the average-mean daily minimum temperature for each year and the mean headwind component (parallel with the runway in use). The lower daily temperature (usually during the night) is used in the study as it is shown to be the best indicator of local climate change (Davy et al. 2017) and has the lowest day-to-day variation (Munasinghe et al. 2012).

Figure 1a and 1b show the trend in the average-mean daily minimum temperature and mean headwind component from the period from 1974 to 2017. For both the trend in temperature and wind presented in Figure 1, the p-values are 0, indicating that the trends are statistically significant. Figure 1a shows that at Chios Airport, the mean daily minimum temperature has on average increased by 0.751 degrees Celsius per decade. In the same period, Figure 1b shows that the mean headwind component has on average decreased by 2.26 knots per decade.



(a) (b)

Figure 1: The trend in (a) average-mean daily minimum temperature and (b) mean headwind component for Chios Airport, Greece from 1974 to 2017.

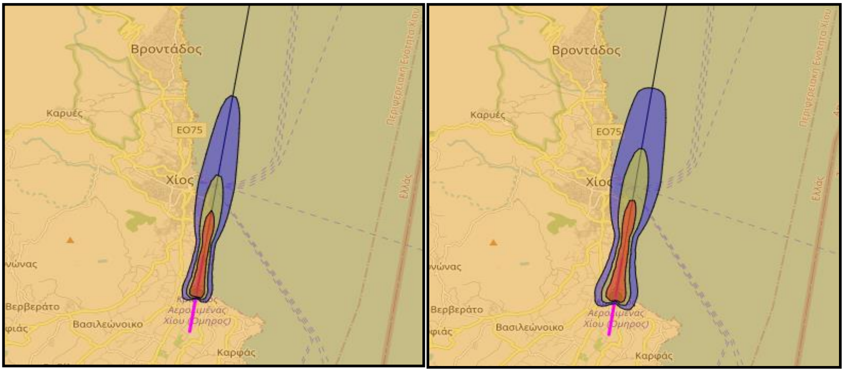
2.3. Aircraft and Departure Procedures

The aircraft chosen for this study were the Airbus A320-232 and Boeing 737-800. Both aircraft are narrow-body aircraft usually operated for short-haul flights. The A320-232 was first certified in 1993 and is fitted with IAE V2527-A5 engines. The Boeing 737-800 conducted its maiden flight in 1997 and is fitted with CFM56-7B engines. Due to the relatively short length of the runway at Chios Airport, both aircraft are unable to take-off at maximum take-off weight (MTOW). Therefore, the maximum permissible take-off weight for mean conditions in the overall period of consideration was used for the study. The aircraft take-off weight is represented in the IMPACT model based on the stage length of the flight with longer stage lengths corresponding to a heavier aircraft. For both aircraft, the stage length of the flight was set at 3500nm. This corresponded to a maximum permissible take-off weight of 77,020kg for the Airbus A320-232 and 76,022kg for the Boeing 737-800 aircraft.

Aircraft operators have adopted their own take-off departure procedures based on environmental, cost and safety considerations. Take-off departure procedures can significantly impact noise on the ground in the vicinity of the airport and therefore, the International Civil Aviation Organisation (ICAO) has established two noise abatement departure procedures (NADP), named NADP1 and NADP2 to minimise noise on the ground. The details of each procedure are outlined in ICAO (2018). NADP1 is used by aircraft operators to minimise noise close to the airport, by climbing quickly to a higher altitude (3000ft) before reducing the climb gradient. NADP2 is used to alleviate noise further afield by climbing relatively slowly early on in the departure before increasing the climb gradient upon reaching 3000ft altitude. For both aircraft, the NADP1 and NADP2 departure procedures were simulated. The study was conducted for departures from runway 01 and 19, with a straight-out departure with no turns. Due to a climb decrement for turning aircraft, the straight-out departure represents the best case scenario for noise levels at ground level and represents a realistic scenario immediately after take-off when aircraft noise levels are at their highest before aircraft begin to follow the Standard Instrument Departure (SID) track.

3. Key Findings

For each simulation run, the noise contour area, in square kilometres, was determined for the L_{den} noise metric, measured in decibels (dB). The L_{den} noise metric is a European standard noise descriptor of noise level based on energy equivalent noise level over a period of 24 hours. The noise level periods are separated into day (07:00 to 19:00 hours local time), evening (19:00 to 23:00 hours) and night (23:00 to 07:00 hours), with a 10dB penalty for night-time noise and a 5dB penalty for evening-time noise. Based on average 2017 traffic levels at Chios Airport, the number of aircraft departures during the day, evening and night was 4, 2 and 0 respectively. The L_{den} noise contour areas were determined at the 50dB, 55dB and 60dB noise levels. Figure 2 shows the noise contour levels for an Airbus A320-232 and a Boeing 737-800 departing from Runway 01 at Chios Airport. Table 2 provides the results of all the simulation runs for 1974 (the earliest climate data available for Chios), 1997 (the earliest year that both aircraft were conducting regular commercial operations) and 2017 (the most recent climate data available for Chios). The noise contour areas are given in square kilometres. The IMPACT modelling tool can also estimate the population contained within each noise contour level, to determine the number of people exposed to a particular noise level. The population data is derived from a population density raster dataset provided by the European Environment Agency (EEA). The dataset is based in the 2001 Census data compiled by Eurostat.



(a) (b)

Figure 2: L_{den} Noise contours for departures from Runway 01 at Chios Airport for (a) an Airbus A320-232 aircraft and (b) a Boeing B737-800 aircraft using NADP2. The contours are based on 2017 temperature and wind data. (50dB – Blue, 55dB – Yellow and 60dB – Red).

For this study, we assume a static population and do not account for changes in population density due to the relocation of residents. According to the Hellenic Statistical Authority (2020), the average permanent population of Chios Island between 1991 and 2017 was 52,952 with a standard deviation of 416. Thus, the population of the island has remained relatively constant during this period and changes in population density are likely to be negligible. Table 2 shows that the noise footprint area of the Boeing 737-800 is larger than that of the Airbus A320-232 aircraft by approximately 61% for NADP1 and 52% for NADP2, under similar scenarios. This is due to different engine types and the better climb performance of the A320-232 aircraft. From 1974 to 2017, the climate data in Figure 1 shows that on average the temperature has increased and the mean headwind component has decreased. Higher temperatures and lower windspeeds reduce the climb performance of aircraft due to a lower true airspeed and lower air density which reduce the lift force and engine performance. The result is a vertical trajectory that is closer to the ground and therefore a larger noise footprint occurs for the same L_{den} noise level. Table 2 shows that for each aircraft and both noise abatement procedures, the noise contour areas at all levels increase from 1974 to 2017. The percentage change in the noise contour areas between the two departure procedures NADP1 and NADP2 is a maximum of 0.69% for the Airbus A320-232 and an average difference of 0.24%. Similarly, for the Boeing 737-800 the maximum percentage difference is 0.24% with an average difference of 0.06%. Thus, it can be concluded that neither considered departure procedure is significantly impacted more or less by the changing climate at Chios Airport. Since 1974, the average noise contour area for L_{den} 60dB would have increased by up to 10.7% for an Airbus A320-232 and by up to 10.3% for a Boeing 737-800 had the aircraft been flying since then. Since 1997, both aircraft have been in regular operation and the noise contour area for L_{den} 60dB has increased by up to 4.8% for an Airbus A320-232 aircraft and up to 4.7% for a Boeing 737-800 aircraft, due to the changing climate. At lower L_{den} levels the minimum increase in noise contour area since 1997 has been 3.1%. Figure 3 shows the percentage change in noise contour areas averaged for both runway departures and noise abatement procedures for each aircraft type. While the Boeing 737-800 has a larger noise footprint area than the Airbus A320-232, the percentage change in noise contour area is slightly higher for the Airbus A320-232 aircraft at all L_{den} noise levels. A clear trend is that the percentage change in noise contour area increases for louder L_{den} noise levels between 1974 and 2017 and 1997 and 2017, though for the latter period the change is approximately half. The increase in the noise contour areas close to the airport due to a changing climate has an inevitable impact on the numbers of people exposed to aircraft noise.

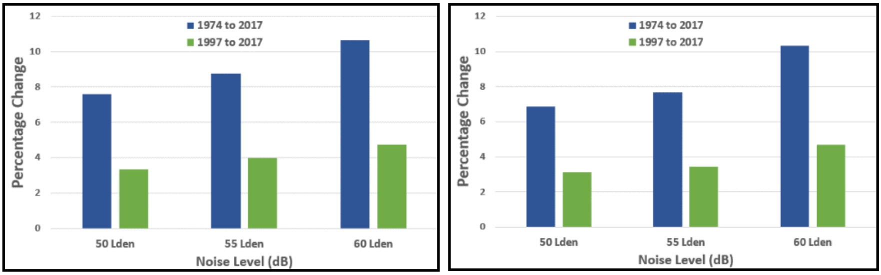
Figure 4 shows the percentage change in the number of people contained within each noise contour level for departures from runway 01 and 19 for the periods 1974 to 2017 and 1997 to 2017. The percentage changes are averaged for aircraft type and the noise abatement departure procedures. Figure 3 and Table 2 show that the area of each L_{den} noise contour increases in all cases with a changing climate. However, this does not always result in an increase in the numbers of people contained within a noise contour. Figure 4 shows that at the 50dB L_{den} noise contour, the population exposed to aircraft noise decreased for runway 01 departures, for the period 1974 to 2017. This is due to the geographic spread of the residential area and its population close to the airport. At Chios Airport, the noise contours resulting for departures from runway 01 are spread across both the land and sea surface. On average the expansion of the noise contour was greater over the sea than the land and therefore less people were contained within this noise level contour. Lower L_{den} noise contours have a greater geographical extent than higher L_{den} noise levels and therefore changes in the number of people exposed to lower L_{den} noise contours noise has a greater dependence on the local geographical spread of the population.

Aircraft Type	Year	Mean Minimum Temperature (Celsius)	Mean Headwind Component (kts)	Noise Abatement Procedure	L_{den} Noise Contour Area (km^2)			Population Contained Within Noise Contour Area		
					50dB	55dB	60dB	50dB	55dB	60dB
Airbus A320-232	1974	12.4	15.9	NADP1	3.83	1.64	0.675	2530	675	38
	1997	14.1	10.7		4.00	1.72	0.714	2520	796	41
	2017	15.6	6.20		4.14	1.79	0.748	2400	795	44
	1974	12.4	15.9	NADP2	4.87	1.68	0.674	2530	676	38
	1997	14.1	10.7		5.06	1.76	0.713	2525	796	41
	2017	15.6	6.20		5.23	1.83	0.746	2400	795	44
Boeing B737-800	1974	12.4	15.9	NADP1	6.20	2.74	1.00	4010	1550	60
	1997	14.1	10.7		6.42	2.85	1.06	3770	1430	61
	2017	15.6	6.20		6.62	2.95	1.11	3640	1420	180
	1974	12.4	15.9	NADP2	7.40	2.84	1.00	4130	1550	60
	1997	14.1	10.7		7.67	2.95	1.06	3770	1430	61
	2017	15.6	6.20		7.91	3.05	1.11	3640	1420	180

Table 2: Noise contour area and population impacted for aircraft departures from Runway 01 at Chios Airport.

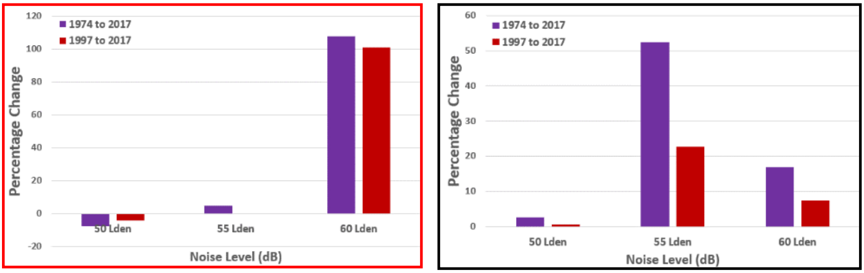
Aircraft Type	Year	Mean Minimum Temperature (Celsius)	Mean Headwind Component (kts)	Noise Abatement Procedure	L_{den} Noise Contour Area (km^2)			Population Contained Within Noise Contour Area		
					50dB	55dB	60dB	50dB	55dB	60dB
Airbus A320-232	1974	12.4	15.9	NADP1	3.83	1.64	0.673	1580	105	30
	1997	14.1	10.7		3.99	1.72	0.710	1640	107	34
	2017	15.6	6.20		4.13	1.78	0.744	1650	158	37
	1974	12.4	15.9	NADP2	4.87	1.68	0.672	1690	107	30
	1997	14.1	10.7		5.06	1.76	0.709	1750	156	34
	2017	15.6	6.20		5.22	1.82	0.743	1760	204	37
Boeing B737-800	1974	12.4	15.9	NADP1	6.19	2.74	1.00	1850	841	48
	1997	14.1	10.7		6.42	2.85	1.06	1870	1210	50
	2017	15.6	6.20		6.62	2.95	1.11	1900	1310	53
	1974	12.4	15.9	NADP2	7.40	2.84	1.00	1970	1170	48
	1997	14.1	10.7		7.67	2.95	1.05	1970	1270	50
	2017	15.6	6.20		7.90	3.05	1.10	1970	1320	53

Table 3: Noise contour area and population impacted for aircraft departures from Runway 19 at Chios Airport.



(a) (b)

Figure 3: Average percentage change in L_{den} noise contour areas from 1974 to 2017 and from 1997 to 2017 for (a) Airbus A320-232 and (b) Boeing 737-800 at Chios Airport.



(a) (b)

Figure 4: Average percentage change in the population exposed to aircraft noise from 1974 to 2017 and from 1997 to 2017 for (a) Runway 01 and (b) Runway 19 departures at Chios Airport.

For runway 19 departures, Figure 4b shows that the number of people contained within all noise level contours increased from 1974 to 2017. For these departures, the noise contours and their expansion due to climate change, are all over land. The largest increases were at the L_{den} 55dB contour level, where on average the population exposed at this noise level increased by 52% and 23% for the period 1974 to 2017 and 1997 to 2017, respectively. For runway 01 departures (Figure 4a), the average increase in population exposure at L_{den} 60dB more than doubled for both time periods, assuming the population remained constant during these periods. In the specific case of a Boeing 737-800 departures from runway 01, the number of people contained within the 60dB L_{den} noise contour increased from 61 to 180 people, in the period 1997 to 2017. This represented a three-fold increase in the population exposed to aircraft noise due to the changing climate.

4. Conclusion

The results of this study show that for the specific case of Chios Airport in Greece, the increase in local temperature and the decrease in local windspeed from 1974 to 2017 has resulted in aircraft trajectories remaining closer to the ground during the departure phase of flight. This in turn has resulted in an expansion of the L_{den} noise contour areas at 50dB, 55dB and 60dB noise levels. Where the expansion of noise contours has been over land occupied by local residents, the numbers of people exposed to higher L_{den} noise levels has increased. In some cases, the population exposure has tripled. Therefore, on average, the changes to the local climate are shown to have an adverse impact on noise levels due to aircraft operations close to an airport. While the results of the present study are only for Chios Airport, it is likely that similar changes in climate at other airports will also have an adverse impact on aircraft noise. Chios Airport is a relatively quiet airport in terms of aircraft traffic and is located in a location with a relatively small population density. At busier airports located in towns and cities with a much greater population density, similar changes in climate in the past and/or future would have a far greater impact on the population. This study has only considered narrow-body, short haul aircraft operations. There would be societal benefits to extend the current research to larger, noisier aircraft operating at major hub airports to assess the impact of noise due to climate change. The current study also emphasises the importance of environmental impact assessment studies for future airport developments to include climate change impacts on aircraft performance and operations and their subsequent impact on local communities.

5. Acknowledgements

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Bio-Aviation Fuel: Dubai Future Perspective

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Abstract As part of the United Arab Emirates' (UAE) and worldwide aviation goal of reaching net-zero greenhouse gas emissions by 2050, this paper studies the potential of successfully implementing both biofuel "drop-in" alternatives, and aerodynamically efficient configurations to decarbonize the Aviation industry. By analysing various proposed designs, it is concluded that the optimum design has a Transonic Truss Braced Wing (TTBW) configuration and runs on 60% biofuel. This design increases the weight by 1.3%, however, the reduction in emissions and fuel consumption are significant. The study also explores the various biofuel types and resolves camelina seeds as the best choice. A primary cost analysis of biofuel application shows an increase of AED 1,653.18 (≈450 USD) per passenger flying on board 100% biofuel powered aircraft. Yet, looking at the trend of the cost increase with biofuel blend ratio, a solution may exist to this uprising cost of a biofuel powered aircraft.

Key Words *Aircraft Design, Bio-Fuel, Camelina, CO_2 Emission, Transonic Truss-Braced Wing.*

1. Introduction

Biofuel is the fuel derived from biomasses such as animal waste and matter from the plants. Biofuel can be considered as a renewable energy compared to the fossil fuels as the biofuel can be easily replenished, and the feedstock of the biofuel has the capability of absorbing the carbon dioxide to produce the new biofuel, which is same process of photosynthesis (Selin *et.al.*, 2021). This shows that biofuel has the capability of emission reduction which will be beneficial for resolving the global warming issue. Moreover, biofuel is a nontoxic fuel produced in safer methods. (Mazlan *et. al.*, 2015; Powell, 2021). Aircraft are mainly powered by two types of fuel, Jet Fuel and AVGAS, based on their mission and requirements during the flight, which produce many different forms of harmful emissions to the atmosphere especially when the engine is powered up. Since the demand of air travel has increased so did the overall emissions. Accordingly, as the alternatives to fossil fuels are limited, biofuels represent an effective solution to reduce the environmental impact. The term 'biofuel' itself implies that the fuel is sustainable which is derived from organics or biomass (IATA, 2021). This shows that biofuels are renewable energy.

The research focuses on the implementation of bio-aviation fuel used in the modern society which are manufactured from animal fats and plant oils such as algae, camelina, and jatropha produced through hydro processing. These fuels are commonly known as hydro processed renewable jet fuel (HRJ) or hydro processed esters and fatty acids (HEFA) and are described as "drop in" aviation fuel (IEA, 2019).

1.1. Sustainable aviation and Objectives of the research

The UAE and the global aviation industry i.e. British Airways, Cathay Pacific, Finnair, Japan Airlines, Malaysia Airlines, Qantas, American Airlines, Qatar Airways, Royal Jordanian, and etc. have set the goal of reaching net zero greenhouse gas emissions by 2050 (UAE government portal, 2021), align with the "Paris Agreement" (IATA, 2022). In addition, Boeing has committed to fly an aircraft using 100% aviation biofuel by 2030 to reach the net zero emission goal (Biofuel International, 2021). To achieve that, this paper initiates the study on the potential of implementing both biofuel and new aerodynamically efficient aircraft configurations in one design. The main objective of this study is to analyze the effects of using biofuel on the aviation industry. Besides, it is necessary to compare the TTBW aircraft configuration to the basic conventional aircraft at different blended biofuel percentages. The blended configuration of TTBW with biofuel can lowers the emissions to the atmosphere and provides a better aerodynamic performance.

2. Methodology

The methods utilized to determine the design components of the aircraft, such as weight estimation and wing loading, are briefly described in this section.

2.1. Aircraft Design Procedure

Based on aircraft mission profile, shown in Figure 1, which shows the path the aircraft follows during its journey from Engine start-up to shut down, the design process has been started. This process is an iterative process in which the aircraft's minimal weight is calculated.

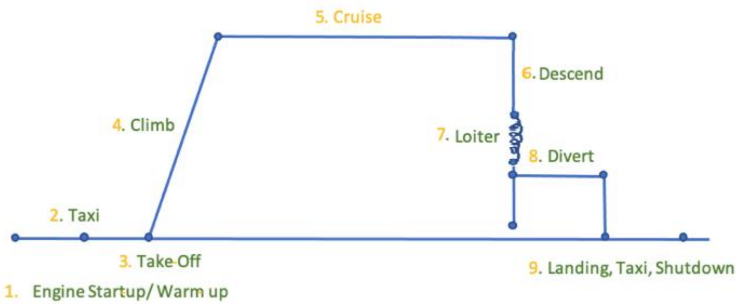

Figure 1: Mission profile for light business jet.

The most crucial step in conceptual design is sizing to calculate the gross take-off weight (W_{TO}). The take-off weight equals the sum of fuel weight, payload weight, empty weight, trapped fuel oil weight, and lastly, crew weight. After determining the values for each parameter in equation 1, iterations are used to get the aircraft's final take-off weight (W_{TO})

$$W_{TO} = W_E + W_F + W_{tfo} + W_{PL} + W_{Crew} \quad (1)$$

where, $W_E, W_F, W_{tfo},$ and W_{PL} are Empty, Fuel, Trapped Fuel Oil, and Payload weights. Following the aircraft weight estimation, design parameters have been selected based on performance analysis. These parameters are:

- Wing area, S
- Take-off Thrust, T_{TO}
- Maximum required Take-off Lift coefficient with flaps up $C_{L_{max,clean}}$
- Maximum required Lift coefficient for Take-off $C_{L_{max,TO}}$
- Maximum required Take-off Lift coefficient for landing $C_{L_{max,landing}}$

The estimations will yield a range of wing loading, W/S, thrust loading, T/W, and maximum lift coefficient values within which specific performance requirements can be met. The highest possible wing loading and the lowest possible thrust loading that still meets all performance standards leads to an airplane with the lowest weight and the lowest cost.

2.2. Transonic Truss Braced Wing (TTBW) Design

Since 2006 Boeing and National Aeronautics and Space Administration (NASA) have been collaborating to introduce a green sustainable aviation vision to the aviation industry. Hence, they have started to work on multiphase research projects titled Subsonic Ultra Green Aircraft Research (SUGAR) (Maldonado, *et al.*, 2020) to reduce the aviation impact on the environment to achieve NASA's 2030-2050 goals (NASA, 2021) for cleaner and greener flying (Bradley, 2017). TTBW is designed to provide the aircraft with a higher aspect ratio (higher wingspan, less induced drag). The conventional cantilever wing suffers from a high wing bending moment at the wing root, while the TTBW design was equipped with two struts at approximately mid-span to reduce the bending moment. The TTBW innovative design focuses on to reducing noise and CO_2 emissions while enhancing the aircraft's performance to fly at higher altitudes and faster than operating aircraft.

Transonic Truss-Braced Wings are currently being employed in future aircraft. It has been concluded this wing configuration is lightweight, ultra-thin, and aerodynamically efficient (Bradley, 2017; Droney *et.al.*, 2018; Maldonado, *et al.*, 2020). TTBW is said to consume less fuel than those with cantilevered configurations. Wind tunnel tests combined with analytical studies on the truss-braced wing configuration have proved that this configuration is lightweight, due to the influence of adding a supporting truss to the wing structure. This allows the longer wing to reduce the spanwise bending moment for a given loading. The higher wingspan also allows for slim truss members thereby reducing the weight of the aircraft. Hence, the combination of both biofuel mixture with TTBW design has exceptional potential for further analysis.

2.3. Application of Biofuel in Aviation Industry

The application of "drop-in" sustainable aviation fuels presents a clear path to decreasing carbon emissions in a short period of time. As a product of the "drop-in" fuel's similar hydrocarbon composition to fossil fuels, they are declared a functionally equivalent substitute; accordingly, no modifications are required to the existing engines, aircraft, or airport infrastructures. Biofuels are usually used as blends with petroleum-based fuels to improve some of their properties such as the ignition quality, fuel flow qualities, and oxidation. Most biofuels are eligible for aviation use under the American Society for Testing and Materials (ASTM) specifications at a maximum of 50% blending level, however the application of biofuels in their pure form has been in the works (Sustainable Aviation, 2020). To present a clear idea on the effects of biofuels on engines Mazlan *et.al.* (2015) simulated the combustion of a twin spool high bypass turbofan engine running on biofuel blends at cruise conditions. Two biofuels were simulated: Jatropha Bio-Synthetic Paraffinic Kerosene (JSPK) and Camelina Bio-Synthetic Paraffinic Kerosene (CSPK). The simulation results display a reduction in Specific Fuel Consumption (SFC) and fuel flow besides an increase in the jet engine thrust when using both biofuels compared to jet A fuel. It is also noted that as the blend ratio increases, the reductions and increase are larger. When powered by 100% CSPK, the engine's thrust increased by 0.12% while the fuel flow and SFC decreased by 1.69% and 1.8% respectively. On the other hand, using 100% of JSPK increased the thrust by 0.09% and decreased the fuel flow and SFC by 2.31% and 2.39% respectively. The results concluded that the application of biofuels has a positive effect on the jet engine performance as they decrease fuel consumption and improve the engines thrust in addition to their role in decreasing emissions (Mazlan *et al*.,2015).

Since the emergence of biofuels and their promising results in being used as an alternative, research to analyse their benefits and potential in decarbonizing the industry have been increasing. Doliente *et. al*. (2020) presented a bibliometric trend on bio-aviation fuel research on a period of 10 years, which showed an obvious jump from only 6 to 73 research in 2019. In the light of the positive results of biofuel application, their implementation in the industry continues to grow.

Year	Airline	Aircraft	Fuel
2008	Virgin Atlantic	Boeing 747	20% blend of biofuel and petroleum jet fuel
2009	KLM	Boeing 747	50% biokerosene mix
2011	Lufthansa	Airbus A321	50% mix of biofuels (Camelina, Jatropha, Animal Fat)
	United Continental Airlines	Boeing 737	40% genetically modified Algae biofuel
	KLM	Boeing 737	50% Cooking Oil
	Air France	Airbus A321	50% Cooking Oil
2012	LAN Colombia (Terpel)	Airbus A320	Refined Vegetable Oil
	Qantas	Airbus A320	50% Refined Cooking Oil
2013	LAN Colombia (Terpel)	Airbus A320	50% blend of Camelina biofuel

Table 1: Initial flights powered by biofuels.

As can be seen in Table 1, the very first flight using biofuel operated in 2008, using 20% biofuel fraction. Flights using 50% biofuel blends commenced in 2011, and since 2016 more than 370,000 flights have operated on biofuel blends (IATA, 2021). Two flights have flown on 100% biofuel in 2018 and 2021 on a Boeing 777 freighter and Airbus A319 neo, the flights show the potential of biofuels replacing fossil fuels in the near future. A wide range of airports have also been refuelling aircrafts with sustainable aviation fuels since 2015, around 14 airports choose sustainable refuelling today, as shown in Figure 2. (IATA: Developing Sustainable Aviation Fuel (SAF), 2021).

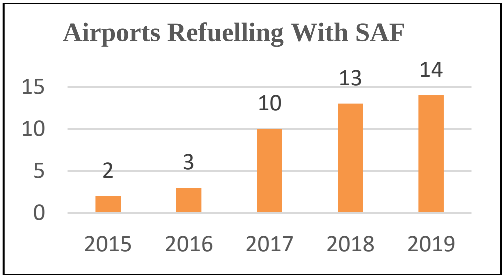

Figure 2: Trend of airports providing SAF supply.

3. Results and Discussion

3.1. Optimum Aircraft Design

The optimum aircraft's design that is intended to be formulated is an aircraft that emit as low as possible discharges into the atmosphere without interfering in its first-rate performance. Hence, to achieve this objective five different options were purposed; in which each option was thoroughly studied and analysed using the PUGH analysis method. The PUGH weighting considered not only the environment and performance, but other aspects including, tail arrangement, landing gear selection, and wing configuration. Table 2 demonstrates the final ratings for each of the option purposed.

Criteria	**Weighting**	**60% Biofuel**	**TTBW + Jet Fuel**	**TTBW+ V-tail + Jet Fuel**	**TTBW + T-tail + 60% Biofuel**	**BWB + Jet Fuel**
Given Name:		Design 1	Design 2	Design 3	Design 4	
Wing Configuration	30%	66.35	76.25	80.1	79.35	37.45
Tail Configuration	5%	76	74	71.5	76	0
Engine	15%	71	82	77.5	81	71
Engine Number	5%	80	82.25	86.25	88.75	82.75
Environmental Impact & Fuel	40%	66.75	67.5	70	82.75	70.5
Aerodynamic Performance	5%	71	71.5	81.5	77.5	83.5
Total	**100%**	**68.6**	**73.56**	**75.61**	**81.16**	**58.4**

Table 2: Final configuration PUGH weighting.

The highest score was established for the business jet with TTBW running on 60% biofuel blend with a T-tail empennage configuration. The proposed design would mark an effective sustainable jet with exceptional environmental and aerodynamic performance. Due to the originality of TTBW in the aviation industry, it would require extensive verification. Therefore, to compare and showcase the design's potential, three designs were calculated prior to the integration of both TTBW and biofuel in one aircraft. Accordingly, 4 designs were opted to explore using the method mentioned earlier in section 2.1, where the designs and its respective findings are summarized in Table 3.

Design / **Results**	**Design 1: Baseline Conventional BizJet**	**Design 2: Conventional BizJet with 60% Camelina Biofuel**	**Design 3: TTBW BizJet with Conventional Fuel**	**Design 4: TTBW BizJet with 60% Camelina Biofuel**
Gross Take Off Weight (W_{TO})	15,000 lb	18,000 lb	12,600 lb	15,200 lb
Wing Loading (W/S)	75 psf	75 psf	87 psf	87 psf
Thrust to Weight Ratio (T/W)	0.48	0.48	0.55	0.55

Table 3: Results of the four selected designs.

The design exploration started off by first determining the weight and optimum wing loading and thrust to weight ratio for a conventional light business jet. It developed a 15,000lb take-off weight with 75 psf W/S and 0.48 T/W aircraft. Gradually and separately each feature was added in Design 2 and 3 to help in analysing the individual effect of biofuel and/or TTBW. Examining the results of the designs, it can be verified that powering the jet by 60% biofuel blend followed a 20% increase in the total take-off weight from 15,000lb to 18,000lb. That is because of the increased mass flow rate required for biofuel to achieve similar adequate performance as the jet fuel. Biofuels have a lower power output compared to jet fuel due to having a lower combustion enthalpy, results in more fuel mass flow to reach the same power output provided by Jet fuel. It should be noted that adding only biofuel did not affected the constraint sizing of the jet, hence having similar values for the W/S and T/W. On the other hand, adding only TTBW with jet fuel caused a 2,400lb decrease in weight, portraying the effect of TTBW's nature on the jet by having high aspect ratio and thin wing. As for the constraint sizing the values of W/S and T/W were settled after several attempts to get the values matching the TTBW's theory of having high W/S and T/W. Finally, approaching Design 4 both the biofuel and TTBW were united to view their effects together, and that ensued a total take-off weight off 15,200lb. Although there is an increase of 200lb, 1.3% additional weight cannot refute the immense positive effect it will have on the emissions due to the biofuel usage. Not to mention the combination of decreased fuel consumption from the TTBW, and the reduced discharge by the biofuel opted in creating an eco-friendly sustainable optimum aircraft design. The wing loading and thrust to weight ratio for Design 4 was similar to that of Design 3 due to the only change being in the wing configuration. Decisively, Design 4's outcomes along with the results of this overall study resolves that the application of biofuel, especially camelina derived, is strongly advised to be utilized in the industry. Employing this framework or related outline all around the world would serve the 2050 net zero carbon emission goal endorsed by many countries, including UAE.

3.2. UAE and Biofuel

The concept of biofuels isn't new to the UAE as it has been in progress since 2011 as displayed in Figure 3. In 2014, the first test flight powered by UAE-produced biokerosene was conducted; soon after that the BIOjet Abu Dhabi initiative was announced, which aims to develop a comprehensive framework for a biofuel supply chain in the UAE. In 2019, the first commercial flight running on UAE plant-produced biofuel took the skies (Etihad, 2019).

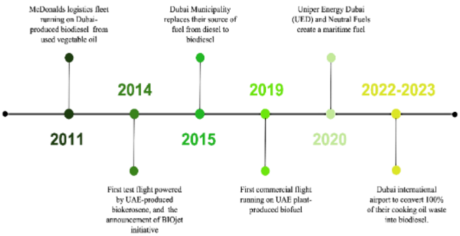

Figure 3: UAE biofuel production timeline.

To select the best plant for oil extraction and biofuel production in UAE, to power the chosen optimum design, an extensive research and comparison was conducted. Jatropha and camelina proved to be the best seeds for biofuel production and were accordingly focused on and compared to the Jet A fuel, as tabulated in Table 4. The results concluded camelina biofuel as the best choice due to its high yield point, low viscosity, standard density, and most importantly its ability to survive harsh environments. To provide camelina with its specific growth requirements and ensure high yield, vertical farming is further suggested as a suitable solution.

Fuel	Advantages	Disadvantages
Jet A Fuel	• Low melting point • Proved • Well established market • Relatively cheaper	• Non-renewable energy source • Source of greenhouse gases • High carbon emission
Camelina Biofuel	• Renewable energy source • Easy production • No threat to food supply • Competitive calorific power	• Expensive • Extensive extraction process • No well-established market
Jatropha Biofuel	• Renewable energy source • Can be grown in harsh conditions • Low production cost • No threat to food supply	• Lower yield through extraction • High viscosity • High density

Table 4: Biofuel comparison – Best available options can be achieved in the UAE.

3.3. Cost Analysis

The current cost breakdown of biofuel powered aircraft was also prepared to determine its potential in the marketplace among its consumers and competitors. Using the distinguished equations and beside the extensive research on biofuel cost and ticket pricing distribution, the following table was established.

Fuel Blends	Fuel cost (USD/nm)	Ticket price /Pax (USD)	Fuel Price /Pax (USD)	Price increase /Pax (USD)	Price increase /Pax (AED)
40% BIO + 60% JET	0.554	19,530.38	2,929.55	179.60	659.69
50% BIO + 50% JET	0.567	19,829.60	2,974.44	224.49	824.57
60% BIO + 40% JET	0.580	20,133.50	3,020.02	270.07	991.99
70% BIO + 30% JET	0.593	20,428.01	3,064.20	314.25	1154.27
100% BIO	0.631	21,333.53	3,200.03	450.08	1653.18

Table 5: Effects of the biofuel price on the fuel expenses for the business jet operating cost and ticket price for the consumers.

Table 5 depicts five scenarios of biofuel powered aircraft traveling merely from Dubai to Hamburg with the only difference in the blend ratios and considering only 15% of the ticket price to be charged for the fuel cost used on the aircraft (Garcia, 2017). Moreover, the main assumption was that the industrial ticket price for the light business jet at the time of writing this paper was averaged to be $2000 per hour (Rivelli, 2022). Acknowledging the aforementioned assumptions from authenticated resources, the main disclosure made was that the price of biofuel flight is more expensive than the conventional jet fuel. Moreover, increasing the biofuel blend tends to upscale the ticket prices per passenger. According to International Renewable Energy Agency (IRENA) 2021 and IATA 2021, the biofuel and jet fuel costs are 2.84 and 1.83 USD/gal (0.77 and 0.50 AED/gal), respectively, designating the biofuel to be more expensive by nature, and hence overpricing the ticket cost. Therefore, a passenger traveling from Dubai to Hamburg onboard an eco-friendly flight with 100% biofuel, will have to pay an extra $450 or AED 1,653.18 for the ticket! Although the price is high, it can be justified that by using biofuel, concerns regarding the greenhouse effect will diminish due to the reduced carbon footprint it liberates. However, authors are suggested to use a less biofuel blend; like the 40% biofuel with 60% jet fuel, to avoid the sudden increase in the ticket pricing that will lean to drive the demand away and negatively impact the aviation industry. In due course and once the consumers and demand settles, the higher blend of biofuels can be introduced gradually to suit and satisfy the market and the law of demand and supply as well.

4. Conclusion

Essentially, the uprising exigency of suppressing emissions all around the globe, and the need to replace the diminishing fossil fuel by an eco-friendly substitute has become the worldwide future concern of many countries. The rise of the Net Zero Goal by number of organizations including the United Nations, for a zero-carbon emission by 2050 has acclaimed and united many nations to focus their resources into producing better solutions; to lower the emissions from various sectors including the aviation industry (United Nations, 2021). Hence, this research aims to contribute to the 2050 zero carbon emission goal by a thorough study on the effect of biofuel on reducing emission by implementing it on a small-scale aircraft type – a six-seater light business jet. The study commenced by first analysing different type of biofuel and its related aspects and outcomes on the aircraft performance and environment consequence. The Camelina biofuel was finalized to be used in the design due to its numerous advantages that benefits not only the environment and the airplane performance, but also the country and/or the place producing it. Afterwards, an immense research time was dedicated to collect and obtain the precise specification for the optimum design through which several competitors' light business jet aircrafts were looked at. Along with the common features for the aircraft, a new concept was also introduced and adopted to three out of the five purposed designs; that is the Transonic Truss Braced Wing. TTBW will increase the effectiveness of this conceptual sustainable design by reducing the fuel consumption up to 10% that will simultaneously lower the emission due to less fuel combustion. Among the five purposed options and through the PUGH analysis, four designs were chosen to perform the calculation using decision making methodology (Roskam, 2017) of conceptually designing an aircraft and estimating its take-off weight. The four designs were: the base; conventional 6 passengers light business jet with jet fuel, conventional jet with 60% biofuel, TTBW + jet fuel, and TTBW with 60% biofuel. Through the conceptual designs analysed, it was concluded that adding either biofuel or TTBW to the base design would affect the aircraft performance. Therefore, the integration of both features together developed the anticipated aircraft performance and emission reduction required to be a factor achieving the 2050 goal of zero carbon emission. The employment of this framework into real life would require contemplating several factors including the cost. Thus, the cost investigation of using biofuels were also determined to infer that the cost of biofuel is actually higher than that of the jet fuel. Nevertheless, the enormous influence it delivers to the environment will automatically compel to seize its application and help subdue the emission problem caused by the aviation sector.

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The Introduction of Sustainable Aviation Fuels Challenges and Options

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Abstract The aviation industry is challenged to reduce its climate impact. The most promising strategy, at least in the short- to medium term, will be the introduction of sustainable aviation fuels (SAF). These fuels feature substantially reduced carbon life-cycle emissions in comparison to fossil fuels. In Europe, a mandatory quota for the use of sustainable fuels will most likely be introduced, starting in the year 2025. The introduction of a blending mandate by governments and the European Commission is associated with a range of challenges. The purpose of this paper is to discuss the economics of climate change mitigation in aviation and the role SAFs can play. The economic issues associated with the introduction of SAFs are analyzed, with a particular focus on the European Commission's proposal for a blending mandate. Several suggestions for improvement are discussed. Despite its relatively high costs, a key finding of the discussion is that SAFs will play an important role in the decarbonization of aviation.

Key Words *Sustainable Aviation Fuels, Climate Change, Aviation Regulation.*

1. Introduction

The global community is challenged to limit the impacts of climate change to a tolerable level. With the Paris Agreement concluded in 2015, it is the legally binding aim to limit the average global temperature increase "to below 2°C above pre-industrial levels" (United Nations, 2015). Promising strategies have been developed in various sectors of the economy to reduce CO_2 emissions., e.g. by scaling up renewable energies or the direct use of electricity in ground transport. These strategies are considered to achieve CO_2 emissions reductions at relatively low costs (Gillingham & Stock, 2018). The aviation industry is particularly challenged, as it is a hard-to-abate sector, where the replacement of the energy carrier by a low carbon alternative is particularly difficult. Jet fuel, as a mixture of different hydrocarbons, features optimal characteristics in terms of performance, energy density and operability (U.S. Department of Energy, 2020). However, it releases CO_2, which was removed from the biosphere millions of years ago and safely stored underground. Other energy carriers either feature an energy density which is too low (e.g. batteries, extensively analyzed in Viswanathan *et al.*, 2022) or, like hydrogen, would require a complete change of the aviation system, including fuel and airport infrastructure as well as the expensive and time-consuming development and certification of new aircraft technology (Noland, 2021). Hence, the introduction of sustainable drop-in hydrocarbon aviation fuels (SAF) from non-fossil origins is considered by many stakeholders as a viable strategy to decarbonize aviation in the short to medium term.

This paper discusses the economic challenges of introducing SAF, such as the economic efficiency of this decarbonization strategy, societal and political implications and the potential impacts of regulatory instruments designed to promote the market uptake of these fuels. The discussion is carried out against the background of the European policy objective of a mandatory blending quota to be introduced by 2025 (European Commission, 2021).

The structure of the paper is as follows: to set the scene, the theory and practice of the reduction of carbon emissions in the aviation sector is discussed, which has led to the regulatory pressure for the introduction of sustainable aviation fuels in Europe. Subsequently, the plans of the European

Commission for a blending mandate are briefly outlined. This is followed by an analysis of the economic and competitive impacts of a blending mandate and a discussion of the potential alternatives. The paper concludes with a summary of the main findings.

2. Reducing Carbon Emissions in Aviation in Theory and Practice

Climate change, which is primarily caused by CO_2 emissions, is a classic example of a negative externality that has been known to economists at least since the work of Pigou (1920). Negative externalities lead to market failure, if they are not considered in the price setting process. One approach to re-instate economic efficiency is to place a uniform price on CO_2 emissions, aligning the private and social costs of emissions. Pigou suggested to install an environmental tax that would cover for the externalities. Another approach is assigning property rights to the atmosphere as "dump" for carbon emissions, following the property rights theory of Coase (2013). The right to release carbon dioxide emissions is then securitized in tradable units, also called permits or allowances. Under economically optimal conditions, the total number of allowances in such a cap-and-trade scheme is limited to a quantity where marginal damage costs equal marginal abatement costs and a socially efficient level of emissions is achieved (Verbruggen, 2021). Emissions will then be priced and a price signal is sent to emitters, which have the choice either to reduce emissions (if this is cheaper than the price of an allowance) or to continue emitting (if abatement costs are higher than the value of allowances). The two approaches (taxes vs. cap-and-trade) feature similarities and differences, which are widely discussed in the economic literature (e.g. Weitzman, 1974; Stavins, 2020).

As straightforward as it looks on paper, implementation of such a first-best solution to reinstate economic efficiency, in reality, is rather difficult. Even within most jurisdictions, carbon emissions are non-uniformly priced - for instance, in Germany, a mix of taxes, carbon prices and emissions trading exist. For instance, aviation is part of the EU-ETS, where CO_2 prices have exceeded 90 €/CO_2 during the year 2022 (European Energy Exchange, 2022), while in the newly introduced national emission trading scheme for fossil fuels used in heating and ground transport is priced at initially 25 €/CO_2 (Federal Government of Germany, 2020). This leads to unequal pricing for each ton of carbon, depending on which sector CO_2 is emitted. In the aviation domain, the international dimension complicates a practical implementation of a uniform carbon price even more. While in Europe, carbon emissions of flights within the European Economic Area are strictly regulated in a cap-and-trade scheme, the majority of emissions in aviation remain effectively unregulated. Doubts are raised as to whether CORSIA, the global carbon offsetting and reduction scheme for international aviation, meets the criteria of economic efficiency in climate protection towards achievement of the objectives outlined in the Paris Agreement (Murphy, 2019; Wozny *et al.*, 2022; Schneider & Wissner, 2022). The scheme does neither strive to reduce emissions below the baseline of the year 2019/2020 nor do the offsets effectively contribute to the removal of CO_2 from the atmosphere. The complexity of assessing the quality of offsets is, for instance, explained by Broekhoff and Spalding-Fecher (2021).

As the existing instruments can be considered as insufficient to effectively reduce the climate impact of aviation, pressure from the European society and politics on the aviation sector has intensified in recent years. This development has become a manifest business risk for the growth of the aviation industry, as sustainable means of travel and the reduction of air trips for business and private purposes have become widespread topics in society.

One topic in the focus of public attention is the potential of SAF to reduce the climate impact of aviation. Depending on the production pathway, the CO_2 reduction potential per unit of fuel can be more than 58 % (Pavlenko & Searle, 2021) compared to a conventional fuel baseline. Some production pathways, under consideration of full lifecycle emissions and indirect impacts, can even feature overall negative emissions. Given the high potential for emissions reductions, legislators on national and European level have started drafting regulations prescribing the use of SAF in future by mandatory quota regulations (European Commission, 2021). Mandatory quotas belong to the group of command-and-control instruments, as opposed to market-based instruments like a cap-and-trade scheme.

The introduction of SAF is, however, not undisputed. From the perspective of economic efficiency, carbon reduction by sustainable aviation fuels is likely to be a relatively expensive strategy, reducing welfare in comparison to a carbon tax (Jiang & Yang, 2021). The economic evaluation of SAF largely depends on its relative costs compared to conventional fuels. Currently, it is estimated that SAF can be two to six times more expensive than conventional jet fuel, depending on the production pathway. This results in abatement costs per ton of CO_2 of 200 € to 500 € for SAF from biogenic feedstocks and potentially even higher costs for power-to-liquid fuels (Pavlenko *et al.*, 2019). Butterworth (2021) finds that in the European Union, two-thirds of CO_2 emissions could be reduced at a cost of less than 200 €/t. In a merit order, wind and solar power, as well as efficiency gains in industry and home heating, feature particularly high reduction potentials, mostly at abatement costs even below 100 €/t.

Hence, it can be argued that a single carbon price would be the first best solution, so that emitters of CO_2 could decide in which sectors carbon emission reductions could be realized at the lowest cost and by which technologies. However, this line of argumentation, being critical of the introduction of SAF, neglects the following points:

First, the learning curve and scale effects are likely to reduce the costs of SAF. Several optimistic studies suggest that in the long run, SAF costs will only be marginally higher than conventional fuels. Wille *et al.* (2022) argue that with a reduction in costs for renewable electricity and in combination with carbon prices for conventional fuel, the cost increase per ticket could be as low as 16 %. Second, the current geopolitical debate shows that a higher degree of energy independence is an important political goal. SAF has the potential to reduce, at least partially, the dependency on potentially politically unstable suppliers of fossil fuels. Third, the societal pressure requires the aviation industry to realize in-sector emissions reductions. A defensive position by the industry, arguing that abatement costs are too high, is unlikely to be accepted by large segments of society and would jeopardize the future development and growth prospects of aviation through a loss of social acceptance. Fourth, due to the international context of aviation, a carbon pricing mechanism putting a uniform price on all CO_2 emitted in aviation globally is unlikely to develop. Fifth, using SAF could significantly reduce the non-CO_2 effects of aviation, which mainly emerge due to soot particles, oxidized sulphur species, NO_x and water vapor emissions (European Commission, 2020). The composition of SAF can be optimized to be low on aromatics and basically free of sulphur particles. This could reduce contrail and cirrus cloud formation. Moreover, local air quality could improve by reducing fine particle emissions and their secondary formation. Hence, the benefits of SAF due not only have to be quantified with regard to CO_2 reduction but also with regards to the reduction of non-CO_2 and local air quality effects. It is currently estimated that non-CO_2 effects currently contribute more than half of the total climate effect of aviation (European Commission, 2020). Sixth, alternative strategies, such as the introduction of more energy efficient aircraft, will be insufficient to effectively reduce CO_2 emissions of aviation in absolute terms. In the past, a decoupling of aviation emissions and traffic could be observed, reducing specific emissions per passenger kilometer. But as traffic growth has exceeded the rate of efficiency improvements, absolute emissions have been growing (Schaefer, 2012). For the next 20 years, Boeing and Airbus expect a traffic growth of 3.8% and 3.6%, respectively (Airbus, 2022; Boeing, 2022). Efficiency improvements, which include both aircraft/engine technology and operational procedures, are in the order of 1.2% (Schaefer, 2012). Hence, absolute CO_2 emissions growth of aviation will be in the order of 2.4-2.6%, which contradicts the objective of keeping global warming to 1.5°C above pre-industrial levels (United Nations, 2015).

To sum it up, the realization of an optimal solution to counter climate change in aviation, according to economic textbooks, will be very unlikely to be realized. When considering a wider set of objectives than CO_2 reduction, the introduction of sustainable aviation fuels can be considered a feasible second-best solution to tackle a wider set of above-mentioned issues.

3. The European Commission's Proposal for a SAF Blending Mandate

3.1. Outline

In July 2021, the European Commission published its proposal ReFuelEU Aviation (European Commission, 2021) for the introduction of a SAF blending mandate as part of the "Fit for 55 package" under the European Green Deal. With this step, the introduction of SAF in Europe is about to be harmonized, as various European governments had previously introduced mandatory SAF quotas on a national level.

The European Commission's proposal stipulates that a growing share of SAF, from initially 2 % in the year 2025 up to 63 % in the year 2050, must be used by all aircraft operators taking off from any airport within the European Economic Area with more than one million passengers or 100,000 tons of freight. Figure 1 provides information on the trajectory of the blending quota over time, which includes a sub-quota for power-to-liquid fuels (also known as e-fuels due to the high intensity of electricity in the production process). This sub-quota is intended to support the technology that, based on current knowledge, has higher production costs than other SAF production pathways. The proposal includes reporting requirements on the fuel required and the fuel uplifted as well as a ban on tinkering. These provisions are intended to reduce potential disadvantages for European airlines in relation to their competitors operating a predominant share of their flights from airports falling outside the scope of the proposed regulation.

The proposal does not include provisions aimed at bridging the cost differential between fossil fuels and SAF, a major concern of airlines who fear that the cost differential will severely impact their competitiveness. The ambitious blending quota also poses technological challenges to the upscaling of SAF production. We estimate that in 2035 approximately 13 million tons of SAF will be required to fulfil the European quota. This figure is expected to increase to over 47 million tons of SAF in 2050 (Figure 2). SAFs from biogenic sources are likely insufficient to cover more than a quarter of this demand (O'Malley *et al.*, 2021). The bulk of the remainder must be covered by power-to-liquid fuels in excess of the mandatory sub-quota. This, in turn, will require a massive scale-up of renewable electricity generation. It is estimated that 42 kWh of electricity is required to produce one kilogram of power-to-liquid fuel (Drünert *et al.*, 2020), which contains, in the end, only 12 kWh of useable energy. This shows the relatively low efficiency of the overall process, which is a strong argument against the widespread deployment of e-fuels until electricity from renewable sources is abundant.

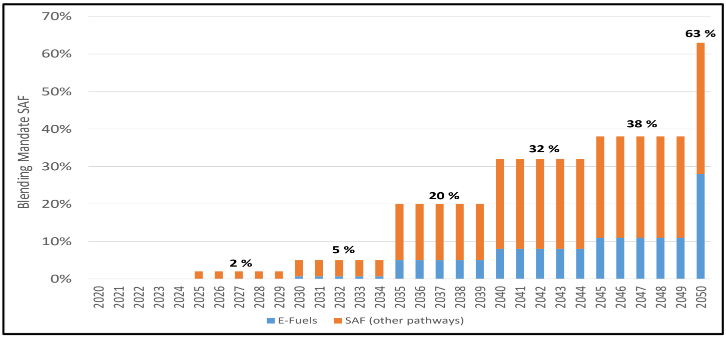

Figure 1: Trajectory of the SAF blending quota as proposed by the European Commission. Source: Own figure based on data of European Commission (2021).

Based on the estimation that 35 million tons of SAF from the power-to-liquid pathway are required in the year 2050, 1,470 TWh of renewable energy would be required as input. This equals half of the total electricity generation and 50% more than the electricity generation from renewable sources in the European Union in 2020 (EUROSTAT, 2022). These figures illustrate the challenge the industry is facing if the targeted SAF quotas are to be met.

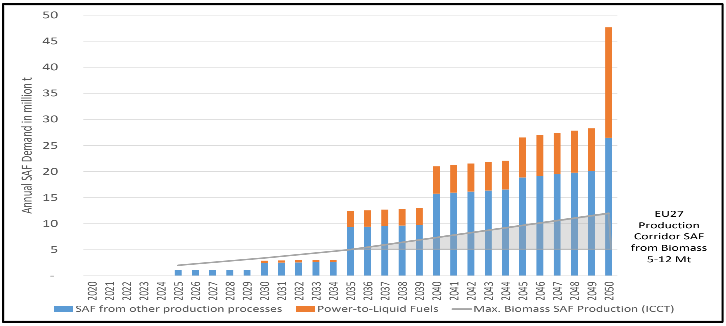

Figure 2: Expected quantities of SAF to fulfil the blending quota as proposed by the European Commission (Grimme, 2022).

3.2. Economic and Competitive Impacts

A mandate to use sustainable aviation fuels at rising quantities over time is likely to increase costs for airlines and, in case a shift on end-users is possible, ultimately for passengers and the shippers of air cargo. With a relatively high share of SAF likely to come from the power-to-liquid production pathway, enormous investments in renewable electricity generation will be required, in addition to the investments for the components of fuel production, such as electrolyzers, syngas processing, syncrude refining and potentially also direct CO_2 air capture.

From a competitive point of view, European airlines fear a disadvantage predominantly in long-haul travel. Non-stop flights, e.g. from Europe to East Asia will be subject to the blending mandate for the full flight distance, affecting the European network airlines with direct services as well as the airlines from third-countries in the region, such as Korean Air, JAL, ANA, Singapore Airlines, Thai Airways and others. As an example, for an origin-destination itinerary from Frankfurt to

Singapore (Figure 3), the full flight distance of a non-stop flight offered by Lufthansa or Singapore Airlines would be subject to the blending mandate, as the flight originates in the European Union. In comparison, only 20% of the flight distance would be subject to the EU blending mandate for an itinerary Frankfurt-Istanbul-Singapore, as the longer flight segment from Istanbul to Singapore does not fall under the EU legislation.

However, it should be noted that IATA, as the main industry organization, has committed to up to 65% SAF deployment by 2050 as part of its 'Net Zero Strategy' published at the 2021 AGM (IATA, 2021). Hence, if airlines took this voluntary commitment seriously, competitive distortions would be minimal. All major network airlines competing in long-haul markets globally are members of IATA and should be subject to voluntary commitment.

Figure 3: Exemplary itinerary Frankfurt-Singapore / non-stop and with a transfer in Istanbul. Source: ww.gcmap.com.

In addition to the issue of long-haul itineraries and the competition with hubs and airlines outside the scope of the EU blending mandate, intra-EU holiday traffic (and destinations) could be affected by traffic flows to be shifted to non-EU locations. For instance, holiday traffic to Spain, Italy and Greece could be diverted to Tunisia or Turkey, where only the outbound segment is subject to the EU blending mandate, but not the return segment. This form of carbon leakage would undermine the effectiveness of the blending mandate. However, conclusive evidence of carbon leakage due to the EU ETS as a similar policy adding costs only to certain route groups is still lacking.

4. Alternative Approaches / Flanking Measures

4.1. Book-and-claim approach

A major issue with the proposal of the European Commission is that the SAF quota must be met at each European airport exceeding one million passengers or 100,000 tons of cargo. The uniform application of the blending mandate puts logistical challenges in the foreground, as SAF must be offered at the quota prescribed by the EU Regulation at each individual airport. This leads to potentially long transport distances from the SAF refineries, which is also associated with additional energy consumption and emissions. Alternatively, it is more efficient to concentrate SAF usage at airports close to the respective refineries. Under such a book-and-claim approach, airlines operating from airports with favorable access to SAF would exceed the quota, while airlines operating from airports with less favorable access would fall below the quota. Compensation could be achieved ex post via tradable certificates so that airlines that used a higher proportion of the more expensive fuel would be compensated. Such a scheme could also incentivize network airlines to invest in building larger SAF facilities at their hub, which could fulfil a large part of their network-wide SAF obligations. Such an approach is likely to be more efficient than the initial proposal of the European

Commission, as it would reduce logistics costs and SAF transport emissions and incentivize larger SAF installations at key hubs.

4.2. Use of Aviation-specific State Revenues for Subsidizing SAF Introduction

A key objective of the blending mandate is to create a market for SAF, which would otherwise not develop because of the cost differentials compared to fossil fuels. Private investment in SAF production is incentivized as there is no alternative for airlines to purchase increasing quantities of SAF to meet the use obligation. In this regard, it is not a necessary consequence to take additional flanking measures to support SAF market development. However, the aviation industry fears competitive distortions with a mandate prescribing the use of more expensive fuel. In order to reduce the cost impacts, various industry suggestions are discussed, which have in common to use of public funds to reduce the cost differential between SAF and fossil fuels. A key objective of the aviation industry is earmarking of revenues from the aviation sector for the introduction of SAF. While in the existing regulations, limited earmarking is envisaged, e.g. for the revenues generated by the sale of allowances in the EU ETS, it does by definition not exist for tax revenues. There is no logical consequence that any taxes collected from aviation activities, such as air passenger duties, must be reallocated to the aviation sector. In case it is the political objective to reduce the costs of the introduction of SAF for the aviation industry, various instruments could be applied.

Contracts for differences are an efficient tool to create incentives for investments in technologies that are not yet competitive in terms of production costs. In such a contract, one party (typically a government branch) guarantees to take over the differential between production costs and market prices of SAF. The instrument is very well suited to overcome the initial obstacle for investments in SAF technology. The historical experience with renewable energy projects like wind and photovoltaic power generation has shown that production facilities constructed at an early stage will not be competitive in the medium to longer term. Between 2010 and 2020 the cost of photovoltaic installations has fallen by 81%, that of wind power by more than 30% (International Renewable Energy Agency, 2021). Nevertheless, such facilities must be built in order to achieve long-term learning curve effects. The advantage of contracts for difference is also the openness concerning technologies to be applied, as a tendering process could only prescribe a certain quantity of low-carbon SAF as an objective, while tenderers can decide on their own which production pathway is the most promising. In the end, the production pathways with the smallest difference between market price and production costs are determined in an order-of-merit approach.

Generally, it is likely that the price differential of the full quantity of SAF to be used in Europe cannot be covered by contracts for difference – if we assume a quantity of about 10 million tons annually in the year 2035 as shown in Figure 2, and an average price difference between SAF and fossil fuel of 1,500 € per ton, public subsidies would amount to around 15 billion € annually. It is doubtful whether European governments would be willing to support the aviation sector by this scale. The majority of costs are likely to be ultimately borne by passengers and shippers of air cargo.

Another conceivable instrument would be a fossil fuel surcharge, which would be redistributed to subsidize SAF price differentials. Such an instrument could be constructed in analogy to the feed-in tariff in the German electricity sector, which was in force from 2000 to 2022. With this instrument, electricity consumers pay a surcharge that encourages investment in renewable energy production. With the help of the renewable energy surcharge, the share of electricity generated from renewable sources in Germany has grown over time to over 45 % in 2020 (Umweltbundesamt, 2021). A positive aspect of the surcharge is that the cost burden is theoretically evenly distributed over all users, while also competitive elements could be integrated, such as competitive tendering for subsidies to bring the most efficient SAF production pathways into the market. A central challenge in defining such a surcharge is the right incentives for SAF producers: If the incentive payment is too low, it would be unattractive to build up production capacities. If the level is too high, windfall profits will be generated, the cost burden on users will be excessive, and incentives to become more efficient in the production of SAF will be too small. The level of such a surcharge will be dependent to a large extent on the price differential between SAF and fossil fuel and the intended SAF quota. Assuming a price differential of 1,500 € per ton in 2035 and 1,000 € per ton in 2050, the quotas outlined in Figure 1 and SAF demand as shown in Figure 2, the surcharge would amount to 375 € per ton of fossil fuel in 2035 and 1,700 € per ton of fossil fuel in 2050. In 2050, almost 50 billion € would have to be re-distributed. In order to relieve users, the surcharge could be subsidized by the state if revenues from taxes or the auctioning of CO_2 allowances were made available for the introduction of the SAF. But overall, these results make it clear that the financial burden will be significant, regardless of who ends up bearing the costs.

Additional flanking measures that could be introduced are also subsidies on investments for research and development or loan guarantees for SAF production facilities in order to reduce the CAPEX cost share. In the USA, tax credits have been successfully applied in order to increase the use of biofuels in ground transport. In August 2022, the United States Senate approved a blender's tax credit of between 1.25 US-$ to 1.75 US-$ per gallon of SAF in order to support the market uptake of SAF (United States Congress, 2022). It is intended that this instrument will support the "Sustainable Aviation Fuel Grand Challenge", with milestones of 3 billion gallons in 2030 and 35 billion gallons in 2050.

5. Conclusion

In this paper, we discussed the economic challenges associated with the introduction of sustainable aviation fuels in light of the proposal of the European Commission for a blending mandate to be applicable at all major airports in the European Union. Although the cost of sustainable aviation fuels makes this approach to CO_2 reduction not economically efficient in the short term, there are a number of arguments in favor of this strategy. The key issue the aviation industry is facing is pressure from society and politics to reduce CO_2 emissions in the aviation sector itself. For the introduction of SAF, different regulatory instruments can be applied. In the EU, a blending mandate is stipulated, which will ultimately impose costs on aviation users (passengers and shippers of cargo), if no flanking measures of support will be added. The aviation industry pushes for earmarking of government revenues to be channeled into SAF production so that the costs for users will be reduced. The overall costs of the transition to SAF for the aviation sector depend to a large extent on the cost differential between SAF and fossil fuel and the quota prescribed in the blending mandate. For the EU, we expect demand for SAF in the order of 47 million tons in the year 2050. But no matter which stakeholder, in the end, has to bear the costs, the transition to SAF will be expensive, especially in the initial phase, when learning curve effects and economies of scale are not yet realized.

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On the Performance of SiC/SiC Ceramic Matrix Composite Material for LPT Rotor Blades of a Boeing 777 - GE90 Jet Engine

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Abstract This paper focuses on the application of SiC/SiC (Silicon Carbide) Ceramic Matrix Composite (CMC) as a material for existing Low-Pressure Turbine blades of commercial aircraft GE90 Jet engines which are currently made of heavy nickel alloys. The choice of SiC/SiC CMC stems from the fact that CMC material is 1/3 of the weight, possessing the same strength with 300 – 400 °C additional temperature resistance in comparison to the currently employed nickel alloys. The performance of the CMC is studied and validated through the Cambridge Engineering Selector (CES) Software and Ansys. It has been found that the consideration of replacing the current LPT blade materials with SiC/SiC CMC as the alternative substantially improves the fracture toughness, strength, fatigue effects, stiffness, maximum service temperature, density requirements and overall prices of the LPT blades employed in commercial aircraft jet engines.

Key Words *Ceramic Matrix, Composites, Silicon Carbide, Turbine, Rotor Blades, Sustainable Aviation.*

1. Introduction

As technology progresses, there has been a constant drive for various methods and ways to enhance the efficiency of different products. The same goes with aviation, as the aviation industry along with other industries, have been trying to spread its wings further with every advancement in technology. In addition, with improved technology, some advanced materials have emerged with the ability to replace the existing ones with much better prospects and functions. In this study, the use of such a material for some applications, namely, "composite material" is considered. The origin of composites basically arises from mixing two or same materials in different forms, namely, the Fibers being impregnated into the Matrix of the mixture. These composites possess excellent strength to weight ratio, up to twice the original material behavior and some are even resistant to high temperatures.

The application of such a composite in a commercial aircraft engine has been explored in this study. The composites have been tried and tested in various platforms where the part is stationery and areas where the part moves while undergoing through some stresses due to motion such as the aircraft wings or engine nacelles (Freeman, 2008). The use of a composite material in a rotating part of an engine is considered in detail. The low-pressure turbine (LPT) of a commercial engine helps in the expansion of the resultant combusted gases and rotates at high rpms (revolution per minutes) in the process. The LPT then also turns the fan of the engine (high bypass turbofans) as they are connected by a common spool, and hence helps in producing thrust for the engine. The LPT has a set of stages where in every stage is comprised of stators and rotors. The stators are designed and positioned in such a way to facilitate the hot gases in impinging them at a particular optimum angle and direct the gases at the rotor, thereby turning the rotor at high rpms.

In this work, the use of the Ceramic Matrix Composite (CMC) as a material for the rotors or blades of the LPT is considered as they are lighter, stronger and more temperature resistant than the existing nickel super alloy used currently. CMCs materials have the ability to replace the rotary components in existing engines, which can be clearly concluded in this paper and henceforth can be readily considered by manufacturers as the new efficient material in aviation when it comes to material selection for rotary components.

1.1. Objectives

For aviation to grow sustainably in tandem with carbon footprint reduction, measures should also be taken considering the financial aspect of the sustainable aviation goal. It should be financially feasible for the airline and the engines manufacturers to implement the carbon reduction scheme and hence the need for lighter and efficient engines is inevitable. Glasgow Climate Pact Oct-Nov 2021 – This work is important considering the recent Climate Change Conference held in Glasgow, UK, which recognized and reiterated the earlier Paris Agreement protocol where it was decided to hold the global temperatures below 2 °C above the pre- industrial era and try to reduce it to 1.5 °C below the pre-industrial period.

Aviation certainly has an important role in curbing the global temperatures and hence different ways and measures should be considered. This work aims at reducing the fuel burn while maintaining the same power band and hence is an important step towards a future of sustainable aviation which aligns with Paris Agreement and the recent Glasgow Climate Pact. The realization of this objective can be achieved through two software, one for the discovery of a new alternative material, namely CES (Cambridge Engineering Selector) for material selection and two, Ansys for further analysis of the LPT blade profile. The performance of the SiC/SiC CMC material within the jet engine operating environment for the LPT blades of a commercial aircraft engine, has been assessed and reviewed in detail with the help of some technical literature materials by "(Zawada et al., 2017)", " (Panakarajupally et al., 2019)" and (Takeshi, 2014). The background for the Ceramic Matrix Composites and its early role in the aviation sector is also discussed in brief.

2. Methodology

2.1. Material Selection through Material Indices and CES software

In a jet engine, the main purpose of the low-pressure turbine blades is to convert the high combustion energy of the hot gases impinging on them after passing through the high-pressure turbine into a high velocity energy by expansion and thereby turning the N1 rotor which includes the fan (stage 1 rotor), low pressure compressors and the low-pressure turbines. To achieve this, the blade should be not only strong enough to endure the bending and fatigue loads, but also include a good amount of fracture toughness and stiffness (Lv, 2019; Hoffman, 2021).

Through the equations for the above-mentioned properties and the resultant material indices, the respective gradients are evaluated and then applied in the CES software. The CES software is a material selector tool developed by Mike Ashby and David Cebon, owner of Granta Materials - Granta Design (Ashby, 2005). This software helps to determine the ultimate material to be chosen under the given constraints and is therefore quite a practical approach to select a new material design for the low-pressure turbine blades (Granta Design). The method used for the SiC/SiC CMC material selection for the intended LPT blade material is followed through equations and CES. Theoretical equations for bending, fatigue, fracture toughness, and stiffness are applied and the gradients to be used as inputs in the CES software are derived from them (Ashby, 1999). The turbine blade is assumed as a cantilever beam, Fig. 1 in a rectangular shape as it is supported only at its roots.

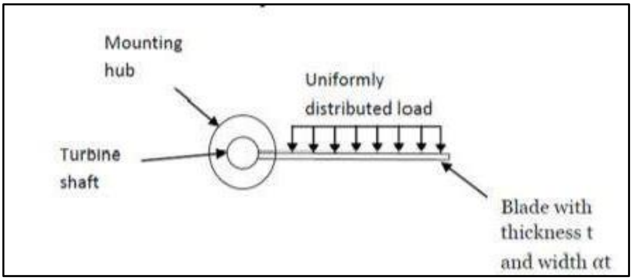

Figure 1: Uniform Loading on a Cantilever Beam (Google, n.d.).

a) Material Index for Bending (Jose, 2021)

With reference to Figure 1 and from the beam bending equation,

$$\frac{M}{I} = \frac{\sigma}{y} \text{ (Ashby, 2005)} \qquad (1)$$

Where, M - bending moment of the blade, I - second moment of area, y - distance from the neutral axis, σ - stress at a distance y from the neutral axis.

For a uniformly distributed load on a cantilever,

$$M = \frac{wL^2}{2} \qquad (2)$$

w - uniform load and L is the length.

$I = \frac{bh^3}{12} = \frac{\alpha t^4}{12}$ (since $A = bh = \alpha t^2$, where h = t and α is $\frac{b}{h}$) (Ashby, 2005)

$$I = \frac{\alpha t^4}{12} \qquad (3)$$

Where t is the thickness and α is the aspect ratio.

$$\text{For } \sigma = \sigma_{max}, \Rightarrow y = \frac{t}{2} \qquad (5)$$

Since cross sectional area $A = \alpha t^2$. Hence $t = \sqrt{\frac{A}{\alpha}}$ (6)

Substituting equation (6) in equation (5), $\Rightarrow \frac{I}{y} = \frac{A^{3/2}}{6\sqrt{\alpha}}$ (7)

$\frac{M}{\sigma} = \frac{F \cdot L}{\sigma_{max}} = \frac{I}{y} = \frac{A^{\frac{3}{2}}}{6\sqrt{\alpha}}$ (Ashby, 2005), hence $A = \left(\frac{6FL\sqrt{\alpha}}{\sigma_{max}}\right)^{2/3}$ and $m = A \times L \times \rho \Rightarrow m = (6FL\sqrt{\alpha})^{\frac{2}{3}} \times L \times \frac{\rho}{\sigma_{max}^{2/3}}$.

Thus, the material index to be maximized for the maximum bending strength and the minimum mass would be $\frac{\sigma_y^{\frac{2}{3}}}{\rho}$ since $\sigma_{max} = \sigma_y$ (yield strength). To justify the magnitude of the gradient, the performance index is equated to a constant, $\frac{\sigma_y^{\frac{2}{3}}}{\rho} = C_1$. Since CES usually plots on log-log scales $\Rightarrow log\, \sigma_y^{\frac{2}{3}} - log\, \rho = log\, C_1$

Rearranging, Yields, $\log \sigma_y^{\frac{2}{3}} = log\, \rho + log\, C_1 \Rightarrow \frac{2}{3} log\, \sigma_y = log_\rho + log\, C_1 \Rightarrow log\, \sigma_y = 1.5\, log\, \rho + 1.5 log C_1$

Where $y = \log \sigma_y$, $x = log\, \rho$ and C = 1.5 $log\, C_1$. Thus, the gradient m is 1.5 for this case.

b) Material Index for fatigue

Considering the condition that the fatigue strength σ_e should be as high as possible, $\frac{wL}{A} \leq \sigma_e$ (Ashby, 2005).
where wL is the total load on the blade. Hence, $A \geq \frac{wL}{\sigma_e}$, $m = \rho \times A \times L \Rightarrow m = \rho \times \frac{wL}{\sigma_e} \times L \Rightarrow m = wL^2 \times \frac{\rho}{\sigma_e}$.
Thus, to maximize fatigue strength with the minimum mass the material index $\frac{\sigma_e}{\rho}$ should be maximized. Taking logs of the expression and rearranging, yields a straight-line equation with a gradient of 1.

c) Material Index for fracture toughness

Assuming the blade to be a center cracked plate with a very large width, the equation would be $K_{1C} = \sigma\sqrt{\pi C}$
Where K_{1C} = Fracture Toughness, C = very small crack, σ = applied stress.
Since $\sigma = \frac{wL}{A}$, $K_{1C} = \frac{wL}{A} \times \sqrt{\pi C}$, $A = \frac{(w\times L)}{K_{IC}} \times \sqrt{\pi C}$ and $m = \rho \times A \times L$
$m = \frac{(\rho\times w\times L)}{K_{1C}} \times \sqrt{\pi C} \Rightarrow m = \frac{w\times L\times\sqrt{\pi C}\times\rho}{K_{1C}}$
Hence the material index to be maximized at a minimum mass for a high fracture toughness would be K_{1C}/ρ and the gradient would be 1.

d) Material Index for maximum specific stiffness

The stiffness of a cantilever beam is given by $S = \frac{F}{\delta}$ (Ashby, 2005); where S – stiffness, F - load applied and δ - deflection.
Since $F = w \times L$, $\delta = \frac{ML^2}{C_1} \times E \times EI$, $M = F \times L = w \times L \times L = w.L^2$ and $C_1 = 8$ for this case.
Therefore,
$S = \frac{8EI}{L^2}$ where E is the Youngs modulus, $I = \frac{bh^3}{12} = \frac{\alpha t^4}{12}$, since $A = bh = \alpha t^2$, where $h = t$ and α is $\frac{b}{h}$.
$S = \frac{8E}{L^2} \times \frac{\alpha t^4}{12} \Rightarrow t = \left(\frac{3L^2S}{2E\alpha}\right)^{\frac{1}{4}}$
$m = \rho \times A \times L \Rightarrow m = \rho \times \alpha t^2 \times L \Rightarrow m = \rho \times \alpha \times \left(\frac{3L^2S}{2E\alpha}\right)^{\frac{1}{2}} \times L \Rightarrow m = \sqrt{\alpha} \times \left(\frac{3S}{2}\right)^{\frac{1}{2}} \times L^2 \times \frac{\rho}{E^{\frac{1}{2}}}$
Thus, the material index that needs to be maximized for better stiffness with minimum mass is $E^{1/2}/\rho$ which makes the gradient as 2.

e) Material Selection using CES

CES software is used to identify the alternative material for the low-pressure turbine blades. CES used the information such as the physical property and the material indices to reach the result. Bending moment, fracture toughness, stiffness and fatigue strength are among the properties that are taken into consideration. A fracture toughness value of 25 MPa.$m^{0.5}$ and a melting T=2000 °C are given as constraints to plot the respective charts. Various charts are plotted with respect to the properties vs density and taking price and the maximum service temperature into consideration. With respect to Figure 2, it is evident that SiC/SiC composite is amongst the leading contenders although not at the lead when it comes to fracture toughness and fatigue strength with respect to density.

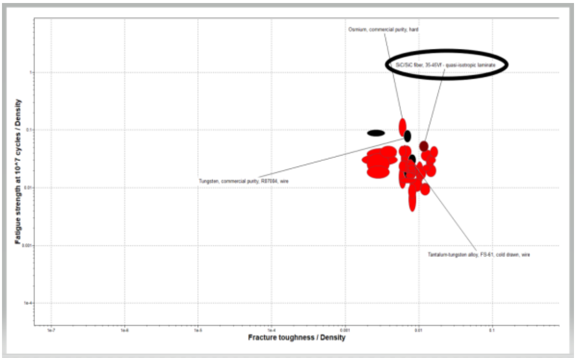

Figure 2: Fatigue Strength vs Fracture Toughness/Density.

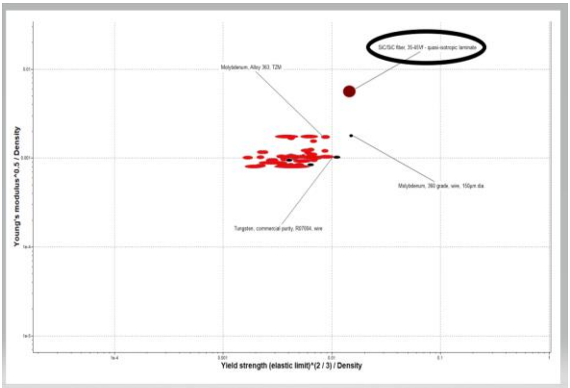

Figure 3: Stiffness vs Yield Strength / Density (CES).

In Figure 3, representing stiffness and yield strength with respect to density, the SiC/SiC quasi laminate composite lead the rest along with molybdenum. However, in Figure. 4, the SiC/SiC CMC is not the cheapest when it comes to the price which can be a downfall, but certainly crosses the 1000 °C mark together with Tantalum-W-Hf and Tantalum tungsten alloy leading the SiC/SiC CMC, at approximately 1300 °C of service temperature which is almost 300- 400°C higher than the current super nickel alloys and can be used for the LPT blades of the current commercial engines. In the case of GE 90 engines (115 lbs of thrust), the exhaust gas temperature (EGT) is around 893 °C and the EGT probes are mounted on the LPT case at the location of stage 2 LPT blades, monitoring the temperatures of the gas exiting the HPT (High-Pressure Turbine) and passing through the LPT (Low Pressure Turbine). In Fig. 5, however, the plot of density vs maximum service temperature clearly shows that SiC/SiC CMC has the lowest density coupled with a high service temperature. Tantalum-W-Hf and the Tantalum tungsten alloys lead on the SiC/SiC CMC in maximum service temperature, the SiC/SiC clearly is the favorite in terms of density.

Having a maximum service temperature of approximately 1300°C and the lowest density amounting to approximately 1/3rd of the current nickel alloys, the SiC/SiC CMCs should be strongly considered for the LPT blades of the current commercial engines. This will help in a substantial amount of cost savings for the engine manufacturers and the airline owing to the reduced fuel consumption for the lighter engines.

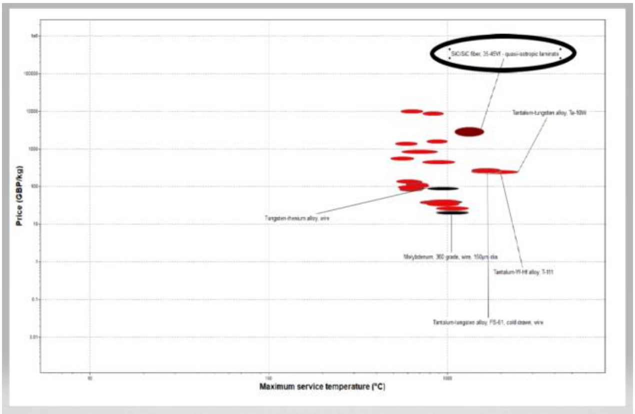

Figure 4: Price vs Maximum Service Temperature (CES).

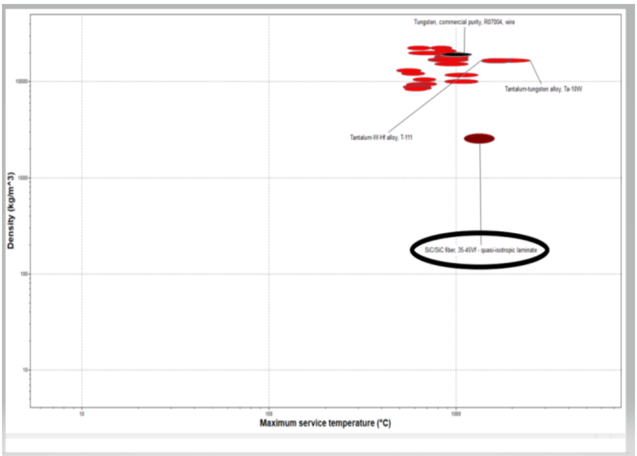

Figure 5: Density vs Maximum Service Temperature (CES).

2.2. Analysis of the Turbine blade profile using Ansys

A combined structural and thermal analysis was carried out of a turbine blade profile using the software Ansys where in the behavior of blade is studied at a revolution of 500 rad/sec and at a temperature of 1000 °C using SiC/SiC Ceramic Matrix Composite as the material. The turbine blade is simulated at a rotational speed of 500 rad/s, that is equivalent to 4774 rpm, revolutions per minutes. This is higher than the N1 = 2447 rpm of the LPT of the GE90, 115 lbs engine at take-off. The 1000 °C temperature applied to the blade profile in Ansys lies well within the EGT range, (LPT temperature) of a maximum 1017 °C for take-off and a maximum of 1003 °C for maximum continuous thrust for a GE90, 115 lbs engine on a standard day. With reference to Fig.6, a rotational speed of 500 rad/s is applied at the base of the blade profile to simulate the blade operation in the jet engine environment where-in the blade is set into high rotational speeds due to the high temperature gases exiting the preceding HPT, High Pressure Turbine and the TCF, Turbine Centre Frame stages.

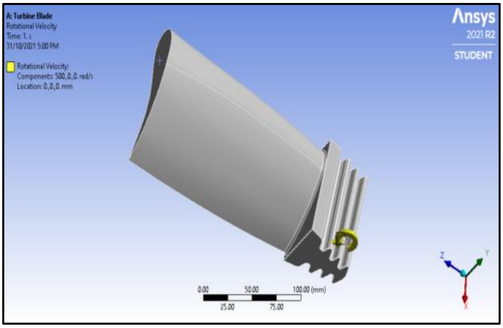

Figure 6: Rotational Speed of 500 rad/sec applied at the base of the Turbine profile.

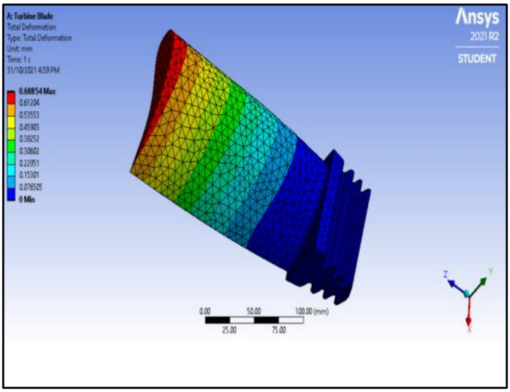

Figure 7: Total Deformation of the Blade profile due to the rotational load.

This high-speed revolution of the blade will create some bending movements causing a temporary elastic deformation of the blade. With reference to Figure 7, it is evident that the blade has undergone a total deformation of maximum 0.68854 mm and a minimum of 0.076505 mm. The maximum deformation occurs at the tip of the blade while the minimum deformation occurs at the root. The deflection is expected due to the rotational load applied but it occurs only at the tip and at a low magnitude. In addition, and with reference to Figure 8, the temperature distribution on the blade profile subjected to a temperature of 1000 °C is visible. A temperature of 1000 ° C is applied on the pressure side of the blade simulating the hot air impinging on the blades. The temperature is lowest at the root of the blade and increases towards the tip.

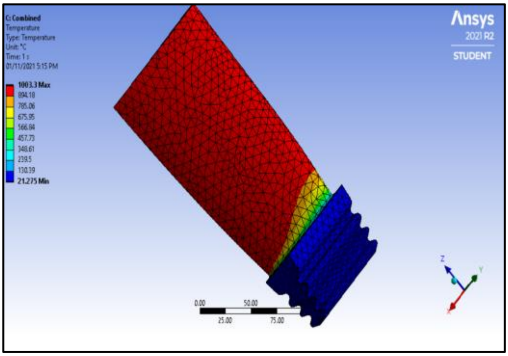

Figure 8: Temperature Profile of the Turbine Blade subjected to 1000 °C.

Some detailed and focused images for the temperature distribution are depicted in Figures 9 and 10.

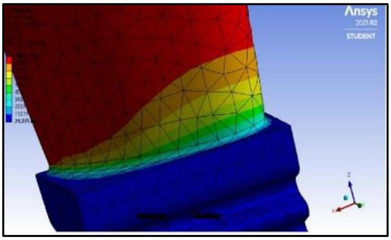

Figure 9: Temperature profile of the Turbine Blade subjected to 1000 °C.

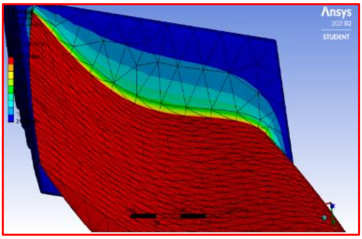

Figure 10: Temperature profile of the Turbine Blade subjected to 1000 ° C.

With reference to Figure 11, the directional heat flux can be observed to be maximum on a very small scale at a particular corner at the bottom towards the training edge of the blade at a value of 11.564 W/mm^2. Some detailed and enhanced images can be seen in Figures 12 and 13.

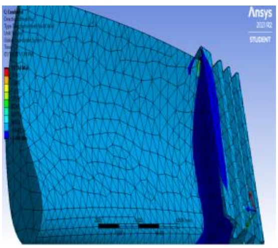

Figure 11: Directional Heat Flux distribution over the Turbine BladeProfile.

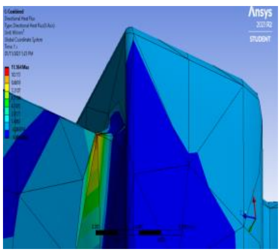

Figure 12: Maximum Directional Heat Flux location on the Turbine Blade Profile.

With reference to Figure 14, the equivalent (Von-Mises) stress distribution over the profile can be seen. Like the directional heat flux, the maximum value for the equivalent (von-mises) stress is concentrated at the bottom trailing edge corner of the blade at a value of 625.11 MPa.

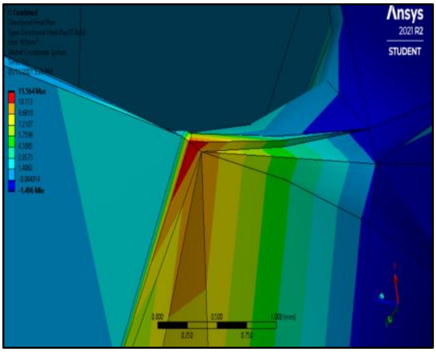

Figure 13: Max Directional Heat Flux Location enlarged view on the Turbine Blade profile.

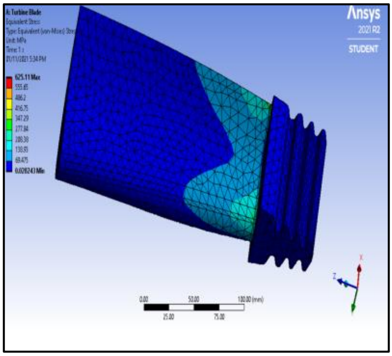

Figure 14: Equivalent (Von-Mises) Stress Distribution over the Turbine Blade profile.

3. Key Findings

The "Cambridge Engineering Selector (CES)" software used in this work is quite adequate to the discovery of an alternative material that can replace the traditional super nickel alloys currently being used for the rotary parts of the aircraft engines. There are some factors that need to be addressed strongly when considering a replacement for the high strength nickel alloys operated in high temperature conditions with high fatigue cycles. Fracture toughness, stiffness, fatigue and bending strengths have been given priority with some constraints. Accordingly, the material indices are derived from the generic equations and the respective gradients are calculated for each property. On the other hand, the software compares various materials within its database and produces a chart of comparison of various materials with respect to each property against one another and against other parameters, namely:

1) Fatigue Strength vs Fracture Toughness with respect to density
2) Stiffness vs Yield Strength with respect to density
3) Price vs Maximum Service Temperature
4) Density vs maximum Service temperature

The materials within the database of the software are already fed with their mechanical and thermodynamic properties and hence in doing such a comparison, it was possible to filter out the best suitable sought material. SiC/SiC Ceramic Matrix Composite (CMC) is among the top contenders for fatigue strength, fracture toughness and stiffness but not the best of them.

It is also expensive compared to some other materials. However, it is superior with respect to its density and maximum service temperature. Engine manufacturers have always been in search of lighter components that could make their engine lighter within the same power delivery band thereby promising great fuel savings for the customers. Fuel savings is not only a financial gain for the customers but also the need for today's climate change scenarios to reduce the emissions and reduce carbon footprints. In addition, Airline manufacturers and clients are also constantly seeking for lighter and greener engines to support their fleets with visions of sustainable aviation in their minds. Light weight should certainly not compromise the strength of the material. Indeed, Sic/SiC CMC light weight material provided additional strength at approximately 1/3 of the weight of the current nickel alloys. The breakthrough is however in the maximum service temperature range which was near to 1300 °C, that is 300-400 °C higher than that of the nickel alloys. All these information and facts that were derived using CES helped identify the SiC/SiC CMC as an effective alternative material for the LPT blades. Although GE company has already implemented CMCs in GE9X engine HPT blades, it would still require some machining for the cooling holes that is required for the HPT blades to be cooled by the secondary air flow to endure the high temperature coming out of the combustion chamber. The machining of the CMCs does involve a lot of precision and is difficult compared to the machining of the nickel alloys. The HPT stages are limited to 2 stages compared to much more LPT stages which will promise less weight reduction.

In this work, the use of the SiC/SiC CMC in the LPT blades has been studied and analyzed as they do not require cooling holes and hence can directly be replaced after being produced by the 3D printing techniques namely the LOM (Laminate Object Manufacturing) process. Owing to the larger number of stages compared to the HPT (6 stages of LPT compared to the 2 stages of HPT for GE90 Engines), the weight reduction that can be achieved by the introduction of CMC LPT blades would be tremendous. Although the material selection could be made both theoretically and analytically by CES, the performance of the SiC/SiC for the intended operation will have to be physically tested under simulated conditions like burner rigs which will be able to mimic the actual engine operating conditions to some extent before testing on the real engine for the LPT blades. The performance indicators could only be analyzed under real world conditions through strain gauges or the ability of the material to withstand a particular run out condition for so many hours so that it can be said this material can successfully replace the current LPT blade material and hence, Sic/SiC CMC material can endure the fatigue cycle and the thermodynamic loads intended for the LPT blades. The turbine blade profile studied in this paper is simulated by "Ansys" to determine its behavior under similar loading and temperature conditions as that of the LPT blades. The blade profile had undergone a static structural analysis coupled with a thermal analysis to forecast the behavior of the LPT blades made of CMC material under operation. This material is assigned to the blade profile and is subjected to 500 rad/sec rotational speed that is higher than what a GE90 LPT engine is usually subjected to. The blade profile showed slight deflections after which it was thermally analyzed with a temperature simulation of 1000 °C on the pressure face of the blade, and the temperature profile and distributions were observed. The temperature profile shows minor changes from the root towards the tip. Nevertheless, some concentrated areas of heat fluxes are also observed near the root of the blade at the trailing edge. Ansys, however, could not successfully show or simulate the thermal effects on the blade profile when impinged with hot gases at 1000 °C. It only indicated the highest temperature area and no detailed thermal failure were observed. Therefore, for SiC/SiC CMC to be considered as an effective alternative material for the LPT blades, it must be tested under more rigorous real conditions, possibly within a burner rig simulating the high temperature operating conditions, so that, it can surely replace the nickel alloys for the LPT blades.

4. Conclusion

This work focusses on the need for a change in the material adoption for the Low-Pressure Turbine blades of aircraft commercial engines from the existing heavier nickel alloys to a much lighter, stronger and a higher heat resistant material known as the SiC/SiC Ceramic Matrix Composite. It has been proven analytically to be the most apt and much required alternative to the nickel alloys in today's aviation industry as it is constantly striving to minimize carbon emissions with sustainable aviation as the primary goal. Sustainability for aviation in terms of financial stability is equally important for aviation along with reduced carbon emissions as it ensures that the aviation sector continues to blossom in the coming years. A considerable amount of fuel savings can be realized with the adoption of such materials helping the engine manufacturers as well as to adapt and produce the blades in line with the latest technologies, such as 3D printing. A transition from metal to composites is imminent for the future of aviation owing to the weight savings. One of the main challenges would be in repairing the parts as it would be difficult to machine the composites compared to the metals. New faster and cheaper manufacturing methods for the bulk CMC composites should also be considered. This will be the other main challenge as it must replace the old manufacturing methods. More rotating and stationary parts of the commercial aircraft engines should be considered for a material change from metal to CMC composite. CMC composite is one of the materials that can be considered as the prime alternative for the nickel alloy rotating parts and the stationary metal parts such as casings and frames.

Therefore, these findings contribute to the consideration of a successful replacement for the LPT blade materials with SiC/SiC CMC with the help of the CES software for material selection and computational software "Ansys" used for various blade profile analysis. CES software utilized successfully to identify SiC/SiC CMC as the new alternative material for LPT blades considering all the constraints for fracture toughness, strength, fatigue, stiffness, maximum service temperature, price, and density requirements. The maximum service temperature for the SiC/SiC CMC has been identified as higher than that of the current nickel alloys by 300-400 °C which makes it a suitable replacement. The density of the SiC/SIC CMC is much lighter and stronger in many aspects than nickel alloys, making it much desirable. The technical specifications of the SiC/SiC CMC provide further confidence in the material as they are furnished following real world operating conditions testing. The effects of BN interphase have been reviewed and has been found very effective in increasing the strength of the fibers and helping in crack alleviations and preventions. Finally, Ansys software helped in the simulation and analysis of the turbine profile subjected to high rpms and high temperature conditions as in the case of real LPT blades within commercial aircraft engines.

5. Acknowledgements

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Modernizing the Chicago Convention: The Challenge of "Sicurity"!

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Abstract In 2020 it was not the first time that humankind had to face a pandemic generated by viruses. Nevertheless, we had not learnt the lesson and were unprepared to fight uniformly against the global pandemic. Unfortunately, that statement holds true for the aviation industry as well. Although the Chicago Convention (1944) provides expressly for the Member States to take effective measures to prevent the spread of communicable diseases by means of air navigation and we have had to launch a sharp attack against viruses several times in history, nevertheless, a uniform and comprehensive regulatory procedural system has not been created. The objective of this paper is to draw attention to the fact that at the time when the industry will struggle against viruses again, it will need a uniform and comprehensive regulation indeed. The experiences necessary for the regulation date back to the last century and we dispose of several results achieved during practical intervention vis-à-vis viruses, which provide foundation for a really comprehensive regulation. Its requirement is the commitment of the Member States of the International Civil Aviation Organisation (ICAO) to introduce new Standards and to observe them completely.

Key Words *Chicago Convention, Modernization, Communicable Diseases, Civil Aviation, COVID–19.*

1. Introduction

Undoubtedly, the virus labelled as SARS-CoV-2 (January 2020) was "not a black swan, a radically unexpected, unlikely event. It was a great rhino, a risk that had become so taken for granted that it was underestimated" (Tooze, 2021). It is clearly seen there have been different kinds of viruses affecting civil aviation activities worldwide:

- Communicable diseases (e.g., influenza pandemics in 1918, 1957, 1968);
- Serious Acute Respiratory Syndrome (SARS-CoV coronavirus!) 2003;
- Highly Pathogenic Avian Influenza (bird flu) (H5N1) 2005;
- Swine Influenza virus (SIV) (H1N1) 2009;
- Middle Eastern Respiratory Syndrome (MERS-CoV coronavirus!) 2012;
- Novel virus of the Avian Influenza (H7N9) 2013;
- Western-African Ebola-virus (EVD) 2014;
- ZIKA virus 2016;
- Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) 2019.

Since the beginnings of human history viruses have been part of our lives. The civil aviation industry has faced this challenge testing humans several times. Despite this, the regulatory side had not prepared entirely for the latest struggle. The present study focuses on the question to what extent the International Civil Aviation Organisation (hereinafter: ICAO) can take up the fight against prospective pandemics. In this battle, the Chicago Convention (1944) and its Annexes have crucial roles since it is via the renewal of the current regulation that uniform intervention by the Member States can be implemented in order to meet the comprehensive requirements preventing the propagation of viruses.

1.1. Objectives

The struggle against viruses has been permanent since they have launched their attacks in newer and newer forms. Consequently, it is necessary and has never been before such topical to intervene uniformly against the next, imminent pandemic, which will guarantee that the performers of the industry intervene efficiently already in the first, initial phase of the pandemic with the instruments of aviation so as to delay the spread of the virus. The study will seek a solution for the question what regulatory instruments can reinforce the achievement of this objective. Therefore, the study has three objectives. *First* of all, to explore what kind of health-related rules the ICAO had made available for the aviation industry before the appearance of COVID-19. We pose the question to what extent this system of rules formed a foundation for the status quo, since mankind has had to deal with the harsh reality of pandemics numerously in the last 100 years. *Secondly*, what kind of uniform action was taken after the COVID-19 had been officially announced as a pandemic and *thirdly*, what kind of future steps must be taken by the ICAO regarding passenger health and pandemic issues.

1.1.1. Current aviation rules

If we examine the aviation rules pertaining to the prevention and hindrance of the propagation of viral diseases, we can see that the Chicago Convention (hereinafter: Convention) highlights the issue as a framework rule and formulates tasks to be observed by the Member States: "The Member States agree that they take effective measures to prevent the spread by means of air navigation of cholera, typhus (epidemic), smallpox, yellow fever, plague and such other communicable diseases as the contracting States shall from time to time decide to designate" (Art. 14). Of course, the list is not taxative, therefore, it needs to be interpreted extensively since there are viruses (e.g., SARS-CoV or Ebola) humankind got acquainted with later.

In the Annexes to the Convention under the Standards and Recommended Practices (SARPs) more detailed rules relying on experience are stipulated:

- Annex 6 – *Operation of Aircraft* – Sections about medical supplies ('Universal precaution kit' on board for managing communicable disease was recommended) and cabin crew health and first aid training;
- Annex 9 – *Facilitation* – Sections about the outbreak of communicable diseases, aircraft disinfection, quarantine at international airports, vaccination certificates;
- Annex 9, Chapter 8 E) deals with the implementation of international health regulations and other provisions specified by the World Health Organisation (WHO). "Implementation of international health regulations and related provisions";
- Annex 11 – *Air Traffic Services* – Section about contingency agreements;
- Annex 14 – *Aerodromes* – Volume I. – Section about aerodrome emergency planning;
- Annex 15 – *Aeronautical Information Services* – Section about aeronautical information updates;
- Annex 18 – *The Safe Transport of Dangerous Goods by Air*.

We cannot fail to mention the relevant ICAO General Assembly Resolutions:

- Assembly *Resolutions* A35–12; A37–13; A39–28; A40–14.

Other regulatory sources made by the ICAO [Procedures for Air Navigation Services (PANS); Regional Supplementary Procedures (SUPPs); Documents, Manuals and Guidance Materials (Docs, GMs)] also contain provisions on the health-related issues of civil aviation:

- e.g., PANS-ATM – the Pilot in Command needs to notify the air traffic control of a suspected case of communicable disease.

Although the contracting States stipulated framework rules on intervention against viruses as early as in 1944 and we can find requirements in several ICAO sources, they are not elaborated and comprehensive, rather general rules, just like the ones included in the Annexes, which are also recommended practices, not norms to be followed mandatorily.

1.1.2. Achievements

We are fully aware that upon the advent of the COVID-19, the world did not intervene uniformly, even the European Union's (EU) Member States introduced different norms, which caused further chaos in air traffic, since even within the unified market of the EU various requirements had to be met upon each flight. It is familiar that certain States prohibited the admission of passengers from certain countries, from States deemed to be infectious (e.g., in the beginning Chinese and Iranian nationals were unwelcome). Subsequently, the ban was not confined to international flights, but in many cases, it concerned domestic flights as well. The airlines tried to adhere to the rule of "social distancing", so the passengers were not seated beside each other, thereby, they could register further losses. In order to maintain their "slots", the airlines operated flights even without passengers. The chaos was enormous, it was obvious that most airlines would go bankrupt unless the government initiated coordinated state and industrial action (Smith and Sharif, 2020).

At the same time, there were rules and measures which had been introduced against the 2003 SARS-Cov and the 2005 Highly Pathogenic Avian Influenza (Bird Flu) (H5N1) by the World Health Organisation (hereinafter: WHO) in a central role and the ICAO. These were instituted expeditiously, since they had been familiar for the industry. Thus, the Member States were obligated

- to examine the passengers more rigorously at the airports of the countries affected by the epidemic (assigned healthcare workers asked loaded questions and measured body temperature with heat cameras);
- the passengers producing the symptoms of the disease were not allowed to travel despite their valid air ticket;
- the passengers had to be informed about the disease or the risk before boarding;
- the passengers arriving from infected areas had to undergo a further medical check;
- at the airports special premises had to be set up in order to accommodate the persons presumed to be virus hosts;
- the crew had to be trained to treat and separate the patient on board producing the symptoms of virus;
- the ground crew was trained both to welcome the airplane carrying passengers infected by the virus and to disinfect the board effectively (ICAO SG 1862/05 AN5/24, 2005; WHO IHR, 2005).

The ICAO and the WHO made recommendations for the procedure of the immediate and temporary closure of the terminal or the whole airport in the final stage. The ICAO always supports the WHO in the implementation of health measures in aviation. The ICAO also implemented appropriate and harmonized preparedness plans made by the stakeholders in close cooperation with the International Air Transport Association (hereinafter: IATA) and the Airports Council International (ACI). As aviation has an outstanding role in the propagation of diseases worldwide, therefore, it is the responsibility and duty of the ICAO and other specialised international institutions to prevent the propagation of communicable diseases via comprehensive cooperation and measures such as

- CAPSCA – Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation (ICAO and WHO, 2006);
- ICAO CART – ICAO Council's Aviation Recovery Task Force,
  Aimed at providing practical, aligned guidance to governments and industry operators in order to restart the international air transport sector and to support recovery from the impacts of COVID-19 on a coordinated global basis;
- TOGD – Take-off: Guidance for Air Travel through the COVID-19 Public Health Crisis, which includes a section on Public Health Risk Mitigation Measures in addition to four operational modules relating to airports, airlines, crew, cargo guidelines, furthermore, it contains recommendations for countries to evaluate passenger medical testing solutions;
- Manual on COVID-19 Cross-Border Risk Management (ICAO Doc 10152, 2020);
- WHO Coronavirus Disease Travel Advice and Guidelines;
- IATA Coronavirus Travel Regulations Map.

Finally, ICAO Member States were recommended (in guidelines) to have a pandemic preparedness plan for aviation, which was integrated into the national plans.

1.2. Justification

No doubt, aviation is mass transportation, which is very sensitive to comprehensive changes and reacts to them immediately. The first question underlying this study is: if the constant growth of scheduled international civil aviation had remained in the ascendant and unswerving despite all international conflicts and world crises, what would have happened before 11th February 2020 and posteriorly? Air carriers find themselves facing minor or major critical situations from time to time, beginning with the oil crisis, terrorist attacks, via natural catastrophes and global recessions to the propagation of infectious diseases, the Oil Crisis (1973), the Iraq versus Iran war (1980), the Gulf War (1992), the Asian economic crisis (1997), the September 11 terrorist attack (2001), the SARS virus (2003), the global financial crises (2008), the eruption of the Icelandic volcano of Eyjafjallajökull (2010) and the Ebola virus (2014).

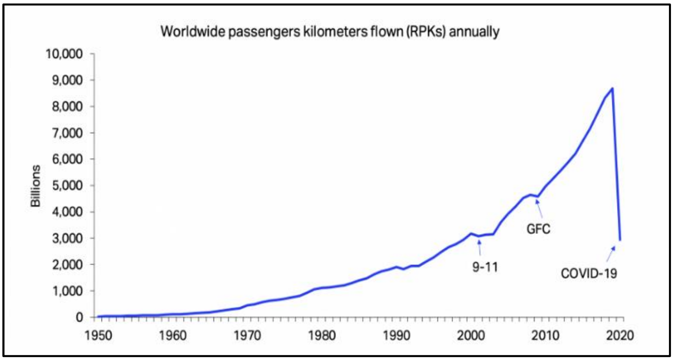

Figure 1: The chart shows clearly how the global passengers kilometres decreased during the COVID-19 period of time (IATA, 2021). Revenue Passenger Kilometres (RPKs) from 1950 to 2020 (IATA, 2021). RPKs is the most accurate airline industry metric system that shows the number of kilometres travelled by paying passengers. [RPKs calculated as the number of revenue passengers multiplied by the total distance travelled. Since it measures the actual demand for air transport, it is often referred to as airline "traffic." For example, Emirates Airlines (EK) operates an Airbus A380 aircraft with a capacity of 521 passengers between Dubai (DXB) and London (LHR). The revenue passengers for the route equal 521 passengers per leg. The distance between the two airports is 5,475 km, which means that the RPK per leg flown is 521 (the passenger demand) multiplied by 5,475 (the distance travelled by the passengers): 2,852,475 RPK/flight leg.]

After so many hits and challenges why did the passenger carriage profile of the civil aviation industry collapse under the preponderance of COVID-19? The answer is harsh: the industry had not done its utmost while it was still possible, the ICAO had not taken sufficient overall preventive measures regarding the fight against communicable diseases. On 11 February 2020, the day when "the common enemy", the COVID-19 was declared to exist (WHO, 2020), the world pandemic was the commencement of a change of paradigm.

2. Methodology

The methodology is based on legal cases and practical activity (see, Points: 2.2, 2.3). The practical part does not encompass the risks proceeding from the carriage of livestock as cargo also remarkable with respect to the propagation of the virus.

2.1. Research

The regulatory background introduced above is manifold, relies on several sources and was made as a result of close institutional cooperation, however, it failed to create uniformity or a harmonised system. Although the Convention specifies the obligation of Member States expressly under Article 14, nevertheless, it stipulates only few underpinning obligations, its background rules are mere recommendations, and its guidelines are utterly insufficient to support uniform intervention. This is disheartening in the awareness that the Chicago Convention does not mention the words aviation security or environmental protection either, nor comprehensive safety/security audit systems, and many other issues are not elaborated within the Convention, nevertheless, these areas have developed and become the strategic pillars (objectives) of the ICAO (see, Security and Facilitation, Environmental Protection) (ICAO, 2022).

One of the deficiencies of the Convention is that in essential issues it was not amended in the past 78 years, more precisely, the Convention was amended in two respects meritoriously, when new passages were incorporated (see, 3 *bis* and 83 *bis*). It is remarkable that the 'pilotless aircraft' was regulated already in 1944 under a separate article (Article 8) or, in our case, the 'prevention of the spread of diseases' (Art. 14), while the significance of these areas in the 21st century does not need to be emphasised, nevertheless, the lawmaker is still indebted with their uniform regulation. Meanwhile, some areas not mentioned in the Convention at all have complex and all-encompassing regulatory background, which qualify as models for other industries.

2.2. Secondary Research

The legal cases demonstrate the deficiencies resulting from the failure of the performers of the industry to elaborate a comprehensive strategy related to the appearance of viruses and to what extent they confined themselves to basic protection (simple preventive measures such as temperature screening, frequent handwashing, social/illness distancing, cough etiquette). For that matter, the WHO as early as in 1998 disclosed 7 cases, when the spread of viruses happened or may have happened on board. The WHO wisely provided guidelines for prevention and control. On the top of that the WHO clearly notified the aviation industry: "Approximately one third of the world's population is infected with Mycobacterium Tuberculosis, and Tuberculosis (TB) is the leading cause of death from a single infectious agent among adults worldwide" (WHO/TB/98.256, 1998).

The US Hawaii State Healthcare Department announced in 1994 that the passenger who later died of tuberculosis (MDR–TB) could have infected several passengers. Before the diagnosis, the 32-year-old victim had flown from Honolulu (HNL) via flight of nearly 8 hours to Chicago (ORD), then from there to Baltimore (BWI). She finally returned, after one month, back to Honolulu. The investigation of the authority revealed that during the journey the woman could have infected several passengers. Later the passengers were symptom-free, but the investigation clarified several real problems. During the journey, the passenger had met 925 persons on board the aircraft, which gave rise to concern because the bacterium of the multidrug-resistant tuberculosis (hereinafter: MDR-TB) spreads quietly, insidiously, primarily via droplet infection (coughing, speaking, sneezing etc.) in the air (Kenyon, Valway, Ihle, Onorato and Castro, 1996).

The WHO informed the industrial performers about the investigations, the character of the risk and the required tasks in a publication. The air transport industry did not react to the prevalent danger uniformly, in spite of the fact that according to the WHO, if the multidrug-resistant tuberculosis (MDR-TB) gains ground, it is "unlikely that it can be stopped"! The WHO report addressed the growing concern about tuberculosis transmission during air travel (including its prevention, the management of infectious passengers, contact tracing and passenger information procedures) within the broader context of tuberculosis (TB) control efforts. The WHO provided guidelines which were applicable to domestic and international civil aviation:

1. the available scientific background on the issue of tuberculosis transmission on aircraft;
2. a review of former practices adopted for the management of patients with infectious TB;
3. suggestions on practical ways to reduce the risk of exposure to MDR-TB on board; and
4. guidance on procedures to be followed when a case of infectious tuberculosis is diagnosed, including tracing and screening of contacts for possible intervention (WHO/TB/98.256, 1998).

2.3. Primary Research

Practice provides cogent evidence that the industry has braced itself after the great shock, since it reacts powerfully to reassure the passengers and sustain the airlines (it is unquestionable that it is the activity of the airlines that facilitates the mitigation of huge losses we are already witnessing). At the same time, the question arises why the industry had not taken drastic steps to create a uniform regulation vis-a-vis pandemic in the former decades. Even the Ebola virus in the midst of the limelight of the media was able to scare away passengers, while we were aware that the virus spreads via blood and bodily fluid infection, not via breathing in and droplet infection, therefore, the passenger was not endangered by the infectious passenger seated next to them (while the common use of the toilet implied a risk factor). Simultaneously, the MDR-TB or other similar, easily communicable viruses may infect anybody at any time on board the aircraft or at the airport. These factors are familiar for everybody, nevertheless, it was only the COVID-19 pandemic that resulted in an array of comprehensive measures in aviation. The Member States of the ICAO may have not adopted standards, since the ICAO relying on the WHO had formed the opinion that it had sufficed to take basic steps for dealing with epidemics. In addition, for the damages caused by the infectious passenger the airline is not liable, since for the physical condition of the passengers, the passengers themselves are responsible. This position could reinforce the belief in the profession that no regulatory environment generating high costs was necessary. In their General Conditions of Carriage, the air carriers expressly and unilaterally stipulate the conditions under which ill passengers and those who need special care (e.g., expectant women, the blind or the physically handicapped) can travel. All air carriers prohibit the travel of infectious passengers.

Besides the General Conditions of Carriage, international law also protects air carriers in such cases, since, if the infectious passenger infects another passenger, that does not qualify as accident pursuant to practice based on Article 17 of the Montreal Convention (1999) (Dias v. Transbrazil Airlines Inc., 1998). Furthermore, frequently the passengers themselves are not aware that they are infectious, whereas the infectious passenger cannot always be identified either, not to mention the extraordinarily expensive and time-consuming procedure. In the case of Tuberculosis (presented in Point 2.2), the inspecting committee with its 30 experts worked 1,200 hours for 8 months to reveal the number of infections resulting from the journey of one passenger and the proceeding risks (Sipos, 2020).

3. Key Findings

In a non-pronounced or outspoken manner, the Chicago Convention has been in need of revision and modernisation (Milde, 2016). This revision is unnecessary with regard to the Annexes to the Convention, since the adoption of the Standards and Recommended Practices (SARPs) by the ICAO Council is based on a relatively rapid and efficient mechanism. On the one hand, it requires the vote of the qualified majority of Member States (the vote of two-thirds of the 36 members on Council of ICAO is enough) (Art. 90), on the other hand, it tracks the regulation of major events in the industry efficiently. This does not apply to the Convention. Any proposed amendment to the Convention shall be approved by two-thirds vote of the 193 Member States of the Assembly (Art. 94 a). Moreover, the Council of ICAO meets in sessions quite frequently every year, whereas the Members of the Assembly meet every three years in practice. Which means that changing and amending the Convention is a very slow and complicated process. Although the Convention has stood the test of time and nearly for 80 years has determined the foundations and system of requirements of the industry uniformly, nonetheless, it lacks areas which in our days determine the industry in its foundations, whereas there are elements which are mentioned in the Convention under framework regulations, but on an international level there is no uniformly unravelled regulatory background. These deficiencies are made up for by life. By way of example, the formulation of security rules was required by terrorist acts (mainly hijacks) (Annex 17 was adopted by the ICAO Council in March 1974), environmental protection was hoisted to become a strategic pillar by irreversible global warming, while in the near future, the pandemic will form the subject-matter of a detailed, wide-ranging, highly important, uniform system of rules. Not by reason of prevention, the greatest trouble could not be avoided, but because the passengers are entitled to travel under healthy, safe circumstances revering human rights.

The main important performers of the industry must act together with the ICAO and other international organisations. They have huge responsibility regarding these issues. The air carriers, airports, the air navigation service providers (ANSP), the maintenance, repair and overhaul (MRO) companies, ground handling and telecommunications companies, insurance companies, aircraft manufacturers, civil aviation authorities (CAA), all of them are playing seeded and prominent roles. Last, but not least there are the passengers. They are frequently relegated to the past, but the gaining ground of passengers' rights, the passenger-centred regulations of private international air law (Montreal Convention, 1999) anticipate that the passenger has acquired their due position. With respect to the fact that aviation is the future form of travelling despite all difficulties and an increasing number of passengers will opt for air transport, far more passengers with health problems will travel by air, who suffer from (not only infectious) diseases or need special care. Ensuring their rights is not only a commercial issue, but also a duty of the authority or the State. Their rights are not only the result, the yield of the legal relation between the contracting parties, but also the universal value to be protected by the ICAO Member States.

4. Conclusion

For the prevention of the propagation of epidemics via the aviation industry, the ICAO makes recommendations to its Member States. The Member States are responsible for the implementation of recommendations. However, adherence to recommendations is not mandatory, there may be differences. Therefore, Standards need to regulate this area. The Standard is a specification, which stipulates a minimum requirement, therefore, its content cannot be emptied out or implemented with less obligations. However, diversion into a more rigorous direction in national or international regulation making is admissible any time. The uniform observance of Standards is recognised by the Member States as necessary and practicable. The Standards are adopted by the Council of ICAO as a mandatory duty [Article 54 l)]. Subsequently, the ICAO Council for convenience designates the technical/procedural rules adopted in its own right and notifies all contracting States of the action taken, such as

- upon arrival at the airport efficient examination in a medical facility prior to embarkation takes place;
- more specific and detailed regulations, exceptional measures (e.g., providing access to medical products) have to be made;
- internationally acknowledged procedures must be observed;
- genuine worldwide cooperation, joining forces, and mutual trust are desired;
- the growing issues and challenges posed by the "sicurity" area needs to be resolved, harmonised and united by Standards and Recommended Practices (SARPs).

However, the regulation maker believed that protection against viruses required merely framework rules and entrusted national law to elaborate this subject. In fact, the Annexes contain partial provisions, but they do not inform the appliers of the law in a uniform manner. The solution of this deficiency is a genuine challenge. For this reason, the Chicago Convention and its system must be revised and the Member States of the ICAO need to regulate, maybe in a separate Annex of the Convention, the standard requirements pertaining to passengers, which will contain uniform health requirements from the viewpoint of public law (not commercial law). The "security" challenges constitute an always growing issue in the industry, on the basis of the struggle against pandemic it needs to be handled in a broad approach and to be regulated in all respects related to the physical condition and all kinds of special needs both of the passengers and professionals (e.g., medical operation on the civil aircraft, medical treatments, uniform requirements concerning the state of health of persons on board, or during embarkation and disembarkation etc.). It is also worth focusing on the uniform provisions on the requirements related to cargo (see, livestock). These provisions, obligations and at the same time rights must be constructed in unity. Thus, the area of "sicurity" could be enforced systematically, guaranteeing the complete realisation of passenger rights.

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The Regulation of Social Aspects in Air Services Agreements: The International and European Perspectives

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Abstract Social aspects relating to aircrew's employment, labour and working conditions have increasingly become predominant in the modern air transport industry. Scarce working conditions, the lack of regulatory harmonisation and the general personnel shortage, which has characterised the first half of 2022, may severely affect the safety of flying. The industry is witnessing to an increasing use of atypical forms of employment for pilots and heterogeneous working conditions, which may greatly vary between countries, may have a detrimental effect on the safe and efficient operation of aircraft. This paper explores how social standards are being addressed in air services agreements worldwide and in Europe.

Key Words *Air Service Agreement, Social, Labour, Aviation, European Union.*

1. Introduction

Social aspects relating to aircrew's employment, labour and working conditions have increasingly become predominant in the modern air transport industry. This is not only because they may expressly affect the very *raison d'être* of flying, that is, safety, but also in light of the fundamental role that pilots and cabin crew play in the airline sector at large. Labour is still predominantly a domestic matter and the lack of regulatory harmonisation is believed to impact aviation at several levels. Scarce working conditions and increasing use of atypical forms of employment for pilots can severely affect the safety of flying as young pilots may have to accept adverse working conditions, low wages, long work shifts and, generally, a less favourable contractual protection. On the other hand, the lack of regulatory harmonisation and coordination concerning aviation labour may determine unfair competition whereby airlines may choose to apply more favourable national labour regulations, even though such national laws may at times do not have any link with the contractual employment itself.

Social issues include a large variety of matters, such as decent work conditions, trade union representation, collective bargaining and social dialogue, gender equality, employment contractual laws and social security. Nevertheless, the scope of this paper is limited to examine how social matters are regarded in air services agreements. This includes a scrutiny as to whether the relevance of social matters is recognised in air services agreements (ASAs) and as to whether any of the most recent agreement provides for a more detailed regulation. In this respect, for example, the analysis of the EU-Qatar agreement of 2019 is used as a case-study as this is the first of its kind to recognise general principles established at the level of public international labour law. In doing so, it is important to first set the scene by analysing what has been done – and is being done – both at the international level, through the United Nations (UN), the International Labour Organization (ILO) and the International Civil Aviation Organization (ICAO), and the regional level of the European Union (EU).

This paper addresses the current status of concern relating to social and labour matters in aviation and explores how these are being given attention in the context of international aviation relations.

In fact, labour and social matters are increasingly becoming important element in the negotiation and drafting of ASAs. In this context, the EU is playing a crucial proactive role by promoting a rather strong aviation policy aiming at setting up basic minimum social standards when negotiating *vis-à-vis* third parties. In particular, the paper will discuss how social standards are currently being dealt with under public international air law, through the activity of the ICAO, and at the European level, with the use of examples from certain EU's aviation agreements recently concluded.

The subject-matter of this paper has become ever more predominant due to the unforeseeable impact of the pandemic of COVID-19, which not only revolutionised the global air transport industry, forcing an unprecedented stall in international air travel, but also resulted in a significant reshape of the industry, with major airlines, operators and/or airports adopting plans of large mass redundancies and addressing matters relating to shortage of personnel. Eloquent in this regard is the situation, which has impacted EU air transport in the summer months of 2022, whereby passengers faced significant disruptions due to.

2. Social Aspects under the International Air Law

2.1. The Chicago Convention 1944 and ICAO

International air transport is governed by the *Convention on International Civil Aviation*, adopted at Chicago on 7 December 1944 (hereinafter also *Chicago Convention 1944*), which is considered the legal constitution of international aviation (Dempsey, 2017, 2), or its *Magna Carta* (Mendes De Leon, 2019, 37). Besides being the legal basis for international aviation activities and a monumental piece of international law-making, the Convention is one of the most successful examples of international treaties, having been ratified by 193 States, as of July 2022.

The Chicago Convention does not address societal aspects of air transport, nor can one find in its articles any reference to the terms 'labour', 'social', 'work' or 'employment' (Trimarchi, 2022, 39). As its driving principle is that of State sovereignty so to ensure a systematic control of international aviation activities, the Convention is mostly concerned with safety and technical aspects of flying (Milde, 2016, 17-20). The Convention also establishes the ICAO, the main international aviation body, mandated to monitor and supervise on safety and navigational requirements. However, one should also note that Article 44 of the Chicago Convention leaves it quite open for ICAO to "*promote generally the development of all aspects of international civil aeronautics*". This shall be read in conjunction with ICAO's authority to ensure safety of international flying, as well as *inter alia* to promote a safe, regular, efficient and economical air transport. This wide angle of action for ICAO conceptually and potentially does include also the authority to investigate into and regulate social matters relating to aircrew, as well as decent work conditions for all those involved in aviation.

Being primarily concerned with technical matters relating to aviation, the Convention talks of the term personnel, whose training, qualification, licensing and requirements are further specified in detail in Annex 1. Annexes to the Convention constitute the traditional 'law-making' instrument of ICAO and comprise Standards and Recommended Practices (SARPs), which provide technical specifications to which Contracting States have to comply with (Mendes De Leon, 2017, 295). However, Annex 1 is silent on the matters relating to work and employment of aviation personnel, as it does not provide any minimum standard or rule concerning labour and social aspects. Only some issues are incidentally touched upon as, for instance, with respect to pilots' and crew members' qualification, flying hours and experience requirement or retirement age. Even though the Chicago Convention 1944 does not directly encompass labour, ICAO has been significantly active in the area of fatigue management, which is strongly intertwined with aspects relating to pilots' and crew members' employment. In this area, it is worth underlining that ICAO has worked in close cooperation with other sectoral associations so as to delineate some basic rules on flight time limitations and fatigue management, compiled in the ICAO Fatigue Risk Management System (FRMS).

The practice and development of international civil aviation has shown, however, that ICAO gained a universal role as the global forum for air transport. This resulted in the Organisation progressively getting involved with matters not originally included in the Chicago Convention. These include *inter alia* fair competition, consumer protection and, most remarkably, environmental protection and climate change. Decent working conditions, as well as gender equality, for instance, are among the matters that ICAO is actively tackling. As recently as 2022, in fact, ICAO has concluded an agreement with the ILO, which builds upon an earlier Memorandum of Understanding (MoU) of 1953, to enhance cooperation in areas of common interest pertaining to the social sphere of international civil air transport. The need for such closer cooperation was even further stressed at the 41st ICAO Assembly in September 2022, where social matters have been on the agenda of the ICAO and where the Organisation renewed its commitment to "*deliver as One*" by enabling effective cooperation with the ILO to strengthen decent work in the aviation sector (ICAO, Working Papers A41-WP/540 and A41/WP/584).

2.2. The United Nations 2030 Agenda and the ICAO Global Social Principles

Among the objectives that the United Nations (UN) has identified in its 2030 *Agenda for Sustainable Development,* many – directly or indirectly – affect the social and labour spheres (United Nations, 2017). Sustainable Development Goal (SDG) no. 8 deals specifically with labour and social relations insofar as it summarises the UN's objective to "*promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*". SDG 8 is further detailed in a list of remarkable and ambitious propositions, which represent the key targets to be achieved. These include promoting the creation of dynamic, sustainable, innovative and people-centred economies, promoting young and women's employment, as well as protecting labour rights and promoting safe and secure working environments for all workers, including migrant workers and those in precarious employment.

ICAO is in fact fully committed to work in close cooperation with States and other UN agencies to support related targets. In this context, ICAO is developing methodologies and conducting studies to measure the importance of the aviation industry and its impact on the global economy and social benefits. These activities include the analysis of the effectiveness of social regulations affecting aviation, with a view to revise and enhance them in order to strengthen the protection of labour rights and the promotion of safe and secure environment to all workers. Already in 2003, at the Fifth Worldwide Air Transport Conference (ATConf/5), ICAO identified some basic principles that should drive the development of air transport (also known as *global principles*), including the respect of social and labour standards (ICAO, 2003, 4.2.).

The No Country Left Behind initiative is a good example of ICAO's effort to assist States in the implementation of Standards and Recommended Practices (SARPs) (ICAO, 2016). In this vein, ICAO made considerable efforts to provide more targeted assistance catering to the needs of States, particularly developing countries. These include: advocacy activities through various meetings to raise the awareness of States and stakeholders of ICAO policies and guidance in the air transport field; promoting understanding of the pivotal role of aviation and its contribution to broader economic development; and encouraging implementation of ICAO policies such as on labour, social aspects, liberalisation, fair competition, consumer protection, taxation and charges (Abeyratne, 2022, 318). In parallel, in order to ensure that highly qualified and educated professionals operate in the international aviation industry, the Organisation also launched its *Next Generation Aviation Professionals* (NGAP) programme (Kearns, 2018). This ensures that enough qualified and competent aviation professionals are available to operate, manage and maintain the future international air transport system and promotes gender equality and decent work conditions for all those involved in aviation.

3. Social Aspects in the European Union Aviation External Policy: The Role of Comprehensive Air Services Agreements

3.1. A Social Agenda for Aviation

In March 2019, the European Commission, along with the contribution of the European Cockpit Association (ECA), the Airline Coordination Platform (ACP) and the European Transport Workers' Federation (ETF), issued a report containing its *Social Agenda for Aviation* (European Commission, 2019). The document, which is part of the broader *Aviation Strategy for Europe*, published in 2015 and further recently reviewed, is the first programmatic policy document adopted by the EU in relation to aviation social and labour aspects and it concerns social, labour and employment matters relating to air transport.

The 2019 Agenda, which maintains a marked focus on aircrew, not only highlights the importance of ensuring fair competition and fair working conditions for the sector, but also envisages a number of critical issues relating to jobs and employment in air transport. These include atypical forms of employment, different working conditions and the lack of harmonisation for social security (Trimarchi, 2022). For instance, the Commission urges action being taken with regard to the quality of training and the hazardous employment schemes of pay-to-fly, temporary agency work, employment via intermediaries and (bogus) self-employment (European Commission, Ricardo Consultants, 2019, 19). The Agenda also notably lays emphasis on the importance of promoting gender equality and work-life balance and of social dialogue in air transport.

Social dialogue and the centrality of work has got back on the agenda of the Union in times of the COVID-19 pandemic. It is estimated, for instance, that only in Europe, over 18,000 pilots lost their job or were put on furlough. The unprecedented shortage that has characterised the latest months has urged social partners, such as the European Cockpit Association (ECA), and European institutions, such as the European Union Aviation Safety Agency (EASA) and the European Commission to address quickly the matter. It was the occasion, for example, for aviation social partners, such as the European Transport Workers' Federation (ETF) to place attention on a number of contentious matters, which include: collective bargaining and social dialogue; fair pay, decent work and fair conditions for all aviation workers; general pay increases; to put an end to precarious work, such as pay-to-fly and self-bogus employment.

3.2. The EU External Aviation Policy

Since 2010, shortly after that the Court of Justice of the European Union (CJEU) rendered its decisions on the so-known Open Skies judgment (Giemulla, 2011), relating to the external aviation action of the EU, the Union has launched a rather intense external aviation policy. This policy not only resulted in a new regulatory environment with regard to EU and international air transport, but also determined an unprecedented restructuring of EU aviation relations *vis-à-vis* third countries.

One of the pillars of the EU's external aviation policy relates to the conclusion of global agreements with other key markets and regions of the world, which are of obvious interest to the European aviation industry (European Commission, 2015). Such key partners are identified by the European Commission, in cooperation with the Member States and it is the same Commission to act for negotiation on the ground of a formal mandate (so-called 'vertical' mandate) granted on a case-by-case basis by the EU Council (Trimarchi, 2022a).

Ever since, the EU has concluded several comprehensive ASAs with virtually most of the major aviation country markets. Good examples are the agreements concluded with the US, Canada, Australia, and recently in 2019 with Qatar (which is still pending signature). Other potential partners are identified in Bahrein, Mexico, Saudi Arabia, China, Oman, UAE, Brazil and Russia. However, negotiations with such countries still have to produce tangible results. The EU, in 2021, also announced the conclusion of negotiations (which started in 2015) for a bloc-to-bloc agreement with the Association of South-East Asian Nations (ASEAN), which would represent the first 'region-to-region' aviation agreement in history. At the time of writing, the exact content of the agreement is under revision and under preparation for signature and is not yet public (Tan, 2021).

3.3. Bilateralism and Social Clauses

Air Services Agreements (ASAs) are the traditional vehicle, which States resort to in order to negotiate and exchange traffic rights and market access. It should not surprise that currently there are over 5,000 ASAs in force worldwide. ASAs developed shortly after the entry into force of the Chicago Convention 1944 and have evolved significantly, having now reached the form of authentic comprehensive aviation agreements (contracts) between States – and at times even between regional organisations, such as for example the so-known Open Skies ASAs. This evolution has also been characterised by a significant scope extension, as agreements, today, not only serve as a means to exchange traffic rights, but also regulate a *plethora* of other aspects relating to air navigation, ranging from security and infrastructure, to competition, taxation and environment and beyond even to social and labour matters.

Even though only in recent years are social aviation matters given increasing relevance in the context of bilateral ASAs, it shall be noted that employment is not entirely disregarded in aviation agreements. In fact, the matter of the applicability of national laws and regulations, including the reciprocal respect of specific employment laws, usually, form the content of a specific clause in virtually all ASAs. This provision, however, relates to the applicability of laws concerning the entering of foreign aircraft into the other party's territory. Observance of national employment regulations is also required with regard to the 'commercial opportunities' of the airlines that are designated to operate in the territory of the agreement's counterparty. Examples of this are various, as, for instance, can be found in the ASA between the UK and Australia of 2012 where it is provided that "*the airlines of each party shall be entitled, in accordance with the laws and regulations of the other party relating to entry, residence, and employment, to bring in and maintain in the territory of the other party managerial, sales, technical, operational, and other specialist staff required for the provision of air transportation*".

Although the vast majority of ASAs still do not formally include specific provisions or explicit references to labour-related issues, most international agreements do generally recognise that employment, labour and respect of decent and fair working conditions have a fundamental role in aviation relations. For example, the EU-US Open Skies Agreement explicitly aims to maximise benefits for labour and consumers, though only at the level of 'declaration of intents', which is not always given application in the text of the agreement or in practice.

The EU is a notable exception to this trend as, in the last decade, has adopted a rather 'aggressive' external aviation policy with the objective of establishing horizontal comprehensive agreements with key partners and to regulate, within such agreements, the largest number of matters relating to air transport (Giemulla, 2011, 78-80). It is a fact, indeed, that the EU strives to include in new horizontal ASAs specific clauses on social and labour matters. The first example of such political will can be found in the EU-Canada Air Transport Agreement. The text of the clause, which governs 'labour matters' provides that "*the parties recognise the importance of considering the effects of this agreement on labour, employment and working conditions.*" Until the recent EU-Qatar Agreement, which will be discussed below, this provision represented a unique example of the social aviation policy carried out by the EU. It is, today, common practice that, while negotiating new ASAs, the European Commission seeks to ensure that the parties' respective policies and laws support high levels of protection in the labour and social domains and that the opportunities created by the agreement- do not weaken domestic labour legislation and standards. It can argued that the EU is playing a fundamental role in the development of social and labour clauses in ASAs. This sentiment seems still not fully supported at the international level, as, for example, ICAO is silent on such matters whereby the ICAO Template Air Services Agreement (TASA), which the Organisation makes it available for individual States, does not include any specific clause on labour, employment or working conditions.

Since economic regulation of air transport has traditionally never been the prerogative of a single *forum* (ICAO or WTO for instance), economic elements of air services have been regulated through ASAs, which have shown to quickly adapt to the new emerging contingencies. As a matter of fact, indeed, today most ASAs contain elements of safety, security, environment, competition, traffic rights, taxation, dispute settlement, as well as political relations. Their scope is so extensive that it would be practical to regularly include social clauses or reference to social/labour regulation. This already happens for some of the most recent agreements concluded at the European level, for example. It can be argued that, should this become ever more relevant in the aviation practice, it could be followed at the global level, or, at least, enhance awareness among international regulators, such as ICAO and ILO (Trimarchi, 2022, 173).

3.4. The Example of the EU and Qatar Air Services Agreement

As the first comprehensive aviation agreement negotiated between the EU and a Gulf State, the ASA between Qatar and the EU sets its ambitions high by aiming to go far beyond mere traffic rights, to provide a platform for future cooperation in areas such as safety, security and environment, as well as to "*improve social and labour policies*". Labour and social matters are considered to be of particular interest given Qatar's poor track record when it comes to legal protection of workers and gender equality in employment.

The EU-Qatar ASA is somewhat revolutionary as it provides a specific dedicated provision relating to 'social aspects', which, for the first time even in the context of aviation, provides for a full commitment of the parties to respect and comply with the basic declarations and conventions from the ILO. These include the Declaration on Fundamental Principles and Rights at Work and its follow-ups, the ILO Decent Work Agenda and the ILO Declaration on Social Justice for a Fair Globalisation of 2008. These documents, which are programmatic and declaratory in nature, recognise basic principles of social protection globally, among which are the right to collective bargaining, freedom of association, no discrimination at work, abolition of child labour and the right to strike. The provision can also be read as to suggest a closer cooperation between ICAO and the ILO in the context of social rights and labour conditions (Trimarchi, 2022, 175).

According to Art. 20 of the agreement, the parties undertake to make best endeavours towards ratifying, if they have not yet done so, the fundamental ILO conventions and other additional material. In practice, this means that both the EU and Qatar undertake to establish their own level of domestic labour protection consistently with their international obligations and commit to ensure their respective laws and regulations are not undermined, but effectively enforced. This seems to be the approach of the EU with its current and future partners, as respect of social and labour standards has become of paramount importance for the Union's external policy. This may also have a promotional nature with regard to countries with poor track records in the area of social rights, or that have adopted certain inappropriate labour practices, if they want to start talks and enter into agreements with the EU. The example of Qatar is eloquent in this respect as, shortly after the conclusion of the ASA, Qatar Airways discontinued the practice of dismissing female aircrew members due to the fact that they are getting married or entering pregnancy, in line with the ILO and EU basic social rights.

4. Conclusion

The regulation of aviation social and labour matters is still in its infancy. As it has been shown in the above analysis, there is no global systematic approach towards how these issues shall be addressed in the context of public international air law. Apart from sporadic and occasional work of ICAO, in fact, much of the regulatory development in this area stems from isolated initiatives and from bilateral ASAs whereby States are willing to ensure respect and promotion of decent work standards, social protection, and commitment to labour law international obligations. The recent events and trends have once again showed the centrality of social matters in a very global and highly regulated industry, such as the aviation one. As seen during summer 2022, aircrew shortage not only hindered the regular and efficient operation of international air transport, but also slowed down the difficult recovery of the industry, which now, after two years, is gradually getting back to decent level.

The EU has proved to be pioneer in this field, with a gradual inclusion of social and labour clauses in its horizontal comprehensive agreement with key aviation partners. While this seems to be one of the pillars of the EU's external aviation policy and is likely to become the rule in future aviation negotiations, it remains to be seen whether this approach will be followed globally. It is the author's understanding that a more systematic and central role of social standards in ASAs may foster awareness and call upon ICAO the task to encourage States to include such aspects in their aviation agreements. In this regard, on the example provided by EU agreements, ASAs should systematically include a 'social clause', which would ideally expressly recognise the basic principles of international social regulation, as well as provide for commitment on the parties on ensuring adequate social protection, fair working conditions, appropriate pay and gender equality.

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Aviation Sentimental Analysis and Multiclass Classification using Natural Language Processing Techniques

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Abstract Sentimental analysis aids to advance focused insight, improve client satisfaction and improve brand image irrespective of the industry. The scope of our work is to use pre-processing techniques to clean the tweets, select a subset of parameters for processing, and characterize these tweets as vectors, and perform a multi-class sentiment analysis with aviation data to test the results with a set of classes (neutral/positive/negative). We used Natural Language Processing (NLP) techniques to understand and extract the useful information from the airline sentiments. Finally, the performance metrics based on various measures is estimated and compared with respect to various United States Airlines. We used four models for our analysis and the results showed that the Logistic regression algorithm performed well comparing other algorithms with around 78% accuracy. The Random Forest, an ensemble model, K Nearest Neighbor (KNN) and decision tree algorithms gave an accuracy of 75%, 69% and 67% respectively.

Key Words *Sentimental Analysis, Multiclass Classification, Natural Language Processing, Aviation Industry.*

1. Introduction

In today’s world most of us share our opinions, reviews about any product, or any service for any industry. This information when utilized properly can help the respective industry in better understanding the customer needs, provide better support, or to compete among their competitors. The airline industry is one of the most significant industry which allows to serve huge number of customers each and every day. Hence, the sentimental analysis is required to analyse the customer reviews which in turn will provide better service and attractive packages for the customer ultimately improving the business strategies related to the revenue and profits in the airline sector. Exploratory Data Analysis (EDA) is the process of gaining a better understanding of data sets by summarizing and visualizing their primary properties. This stage is critical, particularly when it comes to modeling data in order to apply Machine Learning techniques. Histograms, Box plots, Scatter plots, and other plotting options are used in EDA for visualisation purposes. Exploring the data can take a long time. We can define the problem statement or definition on our data set through the EDA process, which is very imperative. Data analytics allows firms to better understand their efficiency and performance, allowing them to make better decisions. An e-commerce corporation, for example, would be interested in analyzing consumer characteristics in order to offer customized adverts to increase sales. If one understands the tools available to analyze data, data analysis may be used to practically any area of an organization. Customers' reviews are analyzed by ecommerce organizations utilizing a good visualization strategy. Exploratory Data Analysis (EDA) is a method of summarizing data by identifying key characteristics and visualizing them using appropriate representations.

The term "classification" refers to the process of categorizing data and grouping it into categories based on similarities. Each training point is assigned to one of N classes. The goal is to create a function that can properly forecast the class to which a new data point belongs when given a new data point. The independent variables or features in a dataset are critical in classifying our data. The concept of multiclass classification involves the dependent or target variable which has more than two classifications. For classification, we employ a variety of techniques such as Naïve Bayes, Decision trees, Support Vector Machine (SVM), Random Forest classifier, KNN, and logistic regression. There are two types of multiclass methods: problem transformation and problem adaptation. The problem transformation groups transform the problem in binary classification problem. While problem adaption group manipulates multiclass data by directly applying some specific algorithm.

Prabhakar et al. (2019) study described how the internet plays a significant role in decision making, many people use various ways and platforms to share their thoughts using the internet resulting in filling the internet with relevant and irrelevant information, making it difficult to fetch the desired information. The study noted how sentimental analysis plays a major role in handling such a problem as well as using various machine learning algorithms in finding the best fit based on the confusion matrix and accuracy of the algorithms. Adeborna et al. (2014) noted that sentiment mining is now commonly associated with the analysis of a text string to determine whether a corpus is of a negative or positive opinion. The study also noted that recently, sentiment mining has been extended to differentiate objective from subjective concepts, as well as recognizing the sources and topics of various viewpoints expressed in textual data sets such as web blogs, tweets, message board reviews, and news. Companies now days can acquire a better knowledge of the drivers and the full breadth of sentiments, companies might use opinion polarity and sentiment topic recognition. These insights can be used to improve competitive intelligence, customer service, brand image, and competitiveness. The study also presented a sentiment mining method for detecting sentiment polarity and sentiment topic in text. A sentiment topic recognition model based on Correlated Topics Models (CTM) and the Variational Expectation-Maximization (VEM) algorithm is included in the approach.

Hussein et al. (2018) noted that a writer generated sentimental analysis about books, people, hotels, products, research and events can be very beneficial for businesses, governments, and individuals. However, the sentiment analysis and evaluation procedure face several difficulties. These difficulties become roadblocks in determining the precise meaning of sentiments and determining the appropriate sentiment polarity. Sentiment analysis is the process of identifying and extracting subjective information from text using natural language processing and text analysis techniques. This survey based on two comparisons among forty-seven studies, the survey addresses the importance and impacts of sentiment analysis issues in sentiment evaluation. The first comparison is focused on the relationship between the structure of sentiment reviews and the challenges of sentiment analysis. The result of the comparison demonstrates domain-dependence, which is an important component in recognizing some sentiment issues. Furthermore, the negation challenge has grown in popularity in all sorts of evaluations, with the only difference being the implicit or explicit meaning. Such a comparison result allows you to evaluate how each sentiment challenge affects the different review structure types. The paper by Hussein et al. (2018) concluded that the appropriate obstacles for evaluative sentiment reviews are determined by the issue type and review format. The second comparison, which is crucial to the accuracy rate, is based on the sentiment analysis problems. Their findings demonstrate the significance of sentiment challenges in evaluating sentiments, as well as how to choose the best challenge to improve accuracy. Another finding explains why sentiment challenges are such a big topic in research. This is shown in the average accuracy outcomes depending on the number of researches in each challenge. The lower the average accuracy rate in a sentiment challenge, the more research there exists.

Kwon et al. (2021) performed topic modelling and sentimental analysis with 27 Asian airlines data which included around 14,000 customer opinions. Based on the analysis they inferred that the meal, service, aircraft seat and the delay of the flight were the major factors contributing to the negative reviews from the customer. Dahal et al. (2019) discussed about performing sentimental data analysis with respect to different geographic locations and the impact of the weather in the customer dissatisfaction. Thus, there are various approaches in literature to perform sentimental analysis in understanding and enhancing customer service and furthermore diverse techniques needs to be evolved to address and handle the complex data being generated.

2. Methodology

2.1. Data

We used publicly available Twitter dataset which consists of 14641 samples with 14 attributes or features separated into three classes 1) 2363 positive sentiments, 2) 9,178 negative sentiments and 3) 3,099 neutral sentiments. The sample in the dataset focussed on the different airline's customer sentiments and opinions. The attributes include airline sentiments and confidence, negative reasons and respective confidence, name of airlines, tweet creation time, location and time zone.

2.2. Data pre-processing

Every time we deal with text data it is practically always never in the form, we expect it to be. The text may have words, punctuation that is not needed. Therefore, in the dataset we used, for the attribute "airline_sentiment" we removed all the special characters, removed all the single character which does not contribute to the text analysis, substituted the multiple spaces with a single space, removed the words prefixed with 'b' i.e. Few words might be stored as byte objects in the data like b"Poor customer support" (The character b doesn't contribute to the text analysis, hence has to be removed). Finally, we converted all the words to lower case. For this purpose, we used the re module from the Regular expressions in Python as described Table 1.

Serial No	Description	Example
1	Remove all the special characters	re.sub(r'\W', ' ', str(feature[sentence]))
2	Remove all single characters	re.sub(r'\s+[a-zA-Z]\s+', ' ', feature)
3	Remove single characters from the start	re.sub(r'\^[a-zA-Z]\s+', ' ' feature)
4	Substituting multiple spaces with single space	re.sub(r'\s+', ' ', feature, flags=re.I)
5	Removing prefixed 'b'	re.sub(r'^b\s+', '', feature)
6	Converting to Lowercase	feature_processed.lower()

Table 1: Data pre-processing using Regular Expression

2.3. NLP

The Natural Language Processing (NLP) is the ability of the computers to understand the text and the spoken words same as the human beings can. NLP combines various statistical, machine learning and deep learning models to process the human language in terms of text, voice data in order to understand the intended meaning. The following describes the different ways to pre-process the text.

Stop words: In computing, stop words are words that are filtered out before or after the natural language data (text) are processed. While "stop words" typically refers to the most common words in a language, all-natural language processing tools don't use a single universal list of stop words.

"stop words" usually refers to the most common words in a language. There is no universal list of "stop words" that is used by all NLP tools in common.

Tokenization: Tokenization can separate sentences, words, characters, or sub words. When we split the text into sentences, we call it sentence tokenization. For words, we call it word tokenization.

TfidfVectorizer: Term Frequency Inverse Document Frequency algorithm to transform text into a meaningful representation of numbers which is used to fit machine algorithm for prediction.

2.4. Model

We divided the data into training and test sets and then we start training the model and make predictions; Based on the study done we choose four different algorithms for our analysis. The KNN algorithm, Logistic regression, decision trees and the ensemble method Random Forest Classifier. We performed the classification using these algorithms and for each algorithm we evaluated the performance metrics using precision, recall, F1-score, and accuracy score with respect to the sentiments.

2.4.1. K Nearest Neighbor Algorithm

The KNN algorithm is a supervised classification technique that uses a large number of labeled points to learn how to identify new records. It looks at the nearest tagged points to a new point before labeling it (Those are its closest neighbors). Because these neighbors vote, the label that the majority of them have is the one for the new point (the "K" represents the number of neighbors it checks) (Gou, J. et al., 2012).
The below formula illustrates the KNN algorithm.

$$\sqrt{\sum_{i=1}^{k}(X_i - Y_i)^2} \quad (1)$$

where, X and Y are the data points, k is the total number of data points for values of *i* ranging from 1 to *k*.

2.4.2. Logistic Regression

Logistic Regression is a technique for predicting data values based on previous observations. To evaluate the outcome, a dichotomous variable is utilized (there are only two possible outcomes). The purpose of logistic regression is to find the model that best explains the association between a dichotomous characteristic of interest and a set of independent variables (Sperandei, S. et al., 2014).

The formula given below describes the principle of the logistic regression for involving multiple classes.

$$p = \frac{\exp\,(a+b_1X_1+b_2X_2+b_3X_3+\cdots)}{1+\exp\,(a+b_1X_1+b_2X_2+b_3X_3+\cdots)} \quad (2)$$

where, *p* is the probability that a case is represented in a specific order, exp is approximately 2.72 which is the exponential, *a* is a constant and *b* is the coefficient of the independent variable.

2.4.3. Decision Tree

When complicated branching occurs in a structured decision process, a decision tree is utilized as a graphical depiction of certain decision situations. The data is subdivided into smaller and smaller subgroups, and a decision tree linked to it is formed consecutively. The tree has leaf nodes and decision nodes at the end. A decision node has two or more branches, and a leaf node represents a category or decision. The best prediction is represented by the decision tree's root node. Decision trees may be used to examine both categorical and numerical data (Charbuty, B., et al. , 2021). Entropy: In machine learning, entropy is a measure of the randomness in the information being processed. The higher the entropy, the harder it is to draw any conclusions from that information.

$$H(X) = -\sum_{i=1}^{n} P(x_i)\, log_b\, P(x_i) \quad (3)$$

Where X is an attribute, P is the probability of occurrence of certain outcome for the attribute. Information Gain: Information gain can be defined as the amount of information gained about a random variable or signal from observing another random variable. It can be considered as the difference between the entropy of parent node and weighted average entropy of child nodes.

$$Gain(S,X) = Entropy(S) - \sum_{v\epsilon} Values(X) \frac{|S_v|}{|S|} \,.\, Entropy(S_v) \quad (4)$$

Where S represents the set of values or instances, S_v is a subset of the given S and the $Values(X)$ is the possible values for X. Gini Impurity: This helps in measuring how the randomly selected element from the set could be mislabelled if it was randomly labelled based on the distribution in the subset. The lower bound is given by 0, with 0 appears in the data set with only one class.

$$Gini(E) = 1 - \sum_{j=1}^{c} p_j^2 \quad (5)$$

2.4.4. Random Forest Classifier

The Random Forest Classifier algorithm is an ensemble technique that is used for classification and regression problems and it is makes uses of multiple decision trees and the bagging method.

3. Key Findings

3.1. Exploratory Data Analysis

The first step to do with the data in hand is to get to know the data collected, which ultimately reduces the workload while performing the data analysis. The Exploratory Data Analysis is the process of determining how to manipulate the data sources to find the solutions or answers which are essential, allowing the process of discovering the patterns, identifying anomalies, testing a hypothesis or assumptions easier for the data scientists, analysts or data engineers. The concept of EDA has been shifting due to the advent of new approaches and convergence between the EDA and other practises, involving data mining and resampling (Yu, C. H., 2010) . The airline sentiment here refers to the sentiment or opinion of the customer which can be positive, negative or neutral.

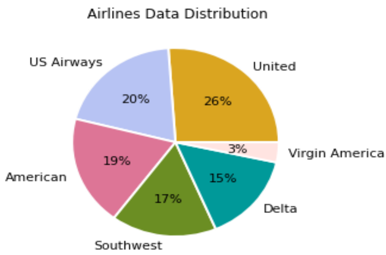

Figure 1: Airline sentiments with respect to the confidence.

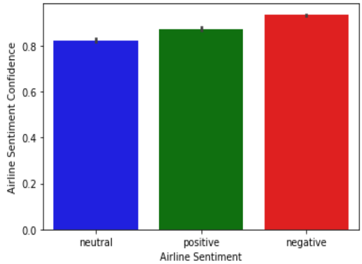

Figure 2: Airline sentiments with respect to the confidence.

The pie-chart shown in Figure 1 describes the data distribution of different airlines including United Airways with 26%, US Airways with 20%, American Airways with 19%, Southwest Airways with 17%, Delta Airways with 15% and Virgin America Airways with 3%. The bar chart in Fig. 2 shows the Airline Sentiment Confidence attribute in the range 0.0 to 1.0 with respect to the three target classes

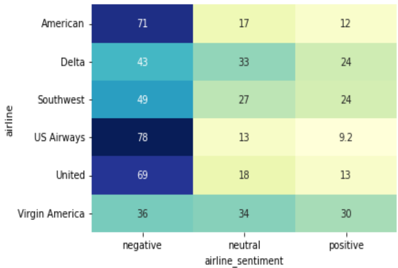

Figure 3: Airline sentiments in percentage with respect to the confidence.

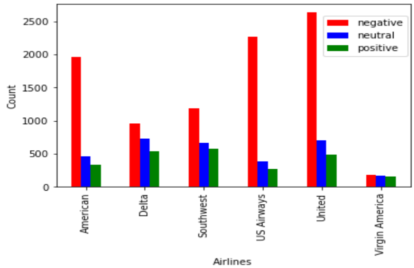

Figure 4: Airline sentiments with respect to the count of sentiments.

Figure 3 represents the percentage of each sentiment positive, negative and neutral for each airlines. As shown in the figure the negative opinion percentage is high for all of the airlines. Figure 4 shows the stacked bar chart for each airline. The United Airways has received more number of negative comments, the next is the US Airways and American airways to receive high number of negative opinions. Comparing all the airlines the Southwest airlines has received high count of postive feedbacks and least positive opionions will be with the Virgin America airlines.

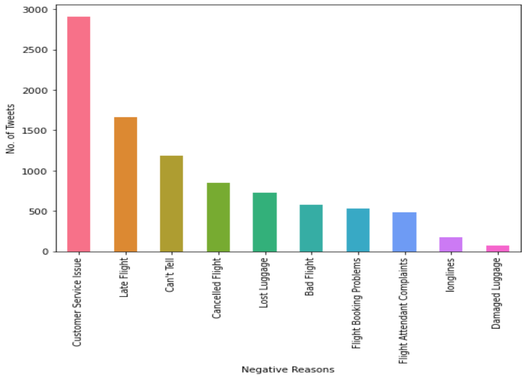

Figure 5: Negative reasons with respect to the number of tweets.

Figure 5 shows the common negative customer opinions received for all the airlines. As shown in the graph more issues were related to the customer service, the delay in flight and flight cancellation was observed as the next highest reasons respectively. Thus, depending on these inferences, the airlines can take appropriate actions or measures to improve the customer satisfaction.

3.2. Performance Calculations

This section discusses the performance metrics calculations for the all the models discussed in the previous section with respect to the train-test distributions/ratios as 80:20, 75:25 and 60:40. The accuracy results based on the precision, recall, f1-score is shown in the Table 2. While evaluating our different models results, we can see that the Logistic regression algorithm performs well comparing other algorithms with around 78% accuracy for all the three data folds. The Random Forest which is an ensemble model gives an accuracy around 75%. The KNN and decision tree algorithms gave an accuracy around 69% and 67% respectively.

Algorithm	Data Distribution (Training: Testing)	Precision	Recall	F1-score	Accuracy (%)
Knn	80:20	0.70	0.69	0.70	69.36
	75:25	0.70	0.69	0.69	68.90
	60:40	0.70	0.69	0.69	69.12
Logistic Regression	80:20	0.78	0.79	0.78	78.82
	75:25	0.78	0.78	0.77	78.46
	60:40	0.77	0.78	0.77	78.19
Decision Tree	80:20	0.68	0.68	0.68	67.69
	75:25	0.68	0.68	0.68	67.56
	60:40	0.66	0.66	0.66	66.12
Random Forest	80:20	0.75	0.76	0.74	75.99
	75:25	0.74	0.75	0.74	75.49
	60:40	0.73	0.75	0.73	74.70

Table 2: Precision, Recall, F1-Score and accuracy values for the different algorithms.

4. Conclusion

In this paper, we performed the Exploratory Data Analysis to get better understanding of the customer opinions based upon different attributes and to summarize and visualize their prime properties. These inferences will help airline industries to better understand their customer and to improve their service by taking better decisions in the future. The airline data with the customer sentiments was transformed by using data cleaning techniques and NLP techniques to more appropriate format that can be used for our analysis. Our work aimed to determine whether the customer opinion or sentiment as positive, negative or neutral. The results show that the Logistic regression algorithm yielded better performance with 78% accuracy using different train-test split ups comparing the other algorithms used for the analysis. The next highest accuracy is yielded using the ensemble model classifier random forest with 75% accuracy. The KNN algorithm and decision trees gave accuracy of 69% and 67% respectively. Thus, we performed multiclass classification by applying different machine learning algorithms and the performance measures were compared and analysed.

5. Acknowledgements

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A Digital multi-modal door-to-door travel planner in direct flight travel

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Abstract This paper introduces an advanced digital tool to assist travellers in their journey, the digital multi-modal door-to-door travel planner. Seamless flow and connectivity are the two most important factors for traveller satisfaction. In addition, modern travellers require flexible, personalised and on-demand travel information. Therefore, an effective digital tool that can help travellers in door-to-door travel is required. In this study, conceptual modelling, digital twinning, and simulation were used to develop and assess a door-to-door travel planner that runs on any personal device, such as a smartphone or tablet.

Key Words *Door-To-Door Travel, Multi-Mode, Digital Twin, Simulation, Optimum Travel.*

1. Introduction

Since it was proposed, the door-to-door concept has grabbed the aviation and travel-related industry's attention and are expected to resolve the problems in the conventional travel model (García-Albertos 2020). As per Schmalz et al. (2021), the door-to-door travel model can provide more opportunities for both the service providers and the customers. By reducing travel disruptions and connecting different travel stages, door-to-door travel can reduce the pain points in the travel process and improve the entire travel experience (Schmalz et al. 2021). As door-to-door travel covers all the processes and activities from travellers' origins to their destinations, estimating the travel route, time, and cost becomes a big challenge, which causes dilemmas in the practical application of door-to-door (Li et al., 2021). Therefore, the research on using digital technologies to improve a practical and useful door-to-door model can support the application of the door-to-door travel model and bring benefits to both the transport industry and travellers post-pandemic period.

1.1. Research objectives

This study aims to develop and assess a holistic and effective digital multi-modal door-to-door travel planner using personal digital devices. This multi-modal door-to-door travel planner enables travellers to manage and control entire travel process from a traveller's perspective, including travel times, travel costs, and transport modes. To achieve these functions, a conceptual model of the digital multi-modal door-to-door travel planner has been built firstly to present the process and the logic of the travel planner. Then, a digital twin model has been built based on the conceptual model, and an Australian domestic travel route has been used as the sample route in the *Arena* simulation software to assess the functionality and usefulness of the travel planner. Thus, the results presented in the finding section prove that the developed digital multi-modal door-to-door travel planner can assist travellers to complete an effective travel process.

1.2. Research rationale

In the conventional travel model, fragmental travel processes and unplanned delays/ disruptions cause travellers to be dissatisfied with the aviation and travel-related industry (Silling 2019). Besides, current digital tools and travel-related applications mainly focus on the selected sectors in the travel process, reducing the connectivity between different travel stages. However, in the recent decade, travellers' travel preferences tend to be seamless, effective, high-tech support, time and cost control, personalised, and flexible (de Graeff 2020; Kluge 2020; Schmalz et al. 2021; Wu & Ma 2022). These factors reflect the key features of the digital multi-modal door-to-door travel planner, which means the travel planner can effectively address the current problems in the conventional travel model. Moreover, as per Babić et al. (2022), involving multi-modal transportation in door-to-door travel has the potential to deliver more effective and flexible services to travellers, and the benefits brought by shifting from intermodality to multimodality are obvious and cannot be ignored. However, current studies on this transformation are insufficient and fragmental, only focusing on selected aspects (Babić et al. 2022). To address this, a comprehensive and holistic model is needed to improve the entire door-to-door travel process, which is the digital multi-modal door-to-door travel planner. The research on this travel planner can contribute to the door-to-door literature since it assessed the high performance of multi-modal door-to-door travel from a traveller's perspective and can provide a guideline for developing an effective multi-modal door-to-door model. Therefore, the study on the digital multi-modal door-to-door travel planner is in the aviation industry, travellers, and academia's interests.

2. Methodology

2.1. Research Approach

As introduced above, this study mainly focuses on developing and examining a digital multi-modal door-to-door travel planner, assisting travellers with their holistic travel experience. Firstly, a conceptual model, which covers all five travel stages in direct flight travel routes, has been developed to present the main logic and major flow of the digital multi-modal door-to-door travel planner. Then, the digital twin has been used to develop an advanced and high-quality digital twin model for the travel planner. Besides, the efficiency and applicability of the developed travel planner have been assessed by simulating the sample route from Melbourne, Australia to Hobart, Australia in *Arena* simulation. The findings of this study specify how the digital multi-modal door-to-door travel planner can provide travellers with a hassle-free door-to-door travel experience.

2.2. Conceptual modelling

Conceptual modelling is one of the main methods in this study, which has been used to build a holistic conceptual model for the digital multi-modal door-to-door travel planner. According to Thalheim (2010), conceptual modelling is a widely applied method that contributes to the main body of the constructs. The purpose of the model is to provide a basis for using the digital twin and simulation in the next step, and it needs to present the logic and contents of the digital multi-modal door-to-door travel planner.

By using conceptual modelling, the main logic and major activities in a direct flight travel process can be built. This conceptual model also provides the fundamental concept of the digital multi-modal door-to-door travel planner, and transfer flights and activities can be added to the model flexibly in the future to cover more travel routes. Therefore, this version of the conceptual model is the source version for other extended versions of the developed travel planner.

2.3. Digital twin

Digital twin (DT) and *Rockwell Arena Simulation* (as "*Arena*" in the following) are the main methods in this research to analyse using digital technologies to improve the door-to-door travel model. The digital twin has been recognised as an effective method by both the industry and academia, which can help industries and organisations achieve Industry 4.0 (Tao et al. 2018). By using digital twins, the physical world can be replicated and predicted in the digital world, which is a technological revolution in the industry (Qi et al., 2021).

In this study, a digital twin has been used to predict and optimise travellers' door-to-door travel by digitising the multi-modal door-to-door travel planner. A digital twin model has been built based on the conceptual model of the digital multi-modal door-to-door travel planner. Then, real-time data and information are obtained to contribute to the processes and activities in the model. The digital twin is one of the best methods which can develop a high-performing digital multi-modal door-to-door travel model from a traveller's perspective.

2.4. Arena simulation

Simulation and digital twins should be used together in this study to generate effective results. In general, simulation provides an opportunity that enables researchers to look insight into a model by using a set of data or information to test or run the model (White & Ingalls 2015). After simulation, the model can be examined, and the results can be obtained to support the implementation and advantages of the model (White & Ingalls 2015).

In this study, *Rockwell Arena Simulation* software is selected to present the digital twin results of the digital multi-modal door-to-door travel planner. *Arena* is a modelling and simulation software which can be used to analyse the performance of designed manufacturing, transport, and other discrete processes (Altiok & Melamed 2010). It is one of the most suitable digital tools to support the digital twin process and generate useful simulation results for the digital model in this research. Moreover, all the processes and stages in the sample route are modelled in *Arena*, which can provide optimised solutions for travellers under different scenarios.

3. Key Findings

3.1. Conceptual model

A conceptual model has been built based on the concept of the digital multi-modal door-to-door travel planner, which covers all the processes and activities in a direct flight travel route. Due to the page limitation, the conceptual model in Fig. 1 and the digital twin model in Fig. 2 can only show the basic framework and main activities. However, the features and the logic of the digital door-to-door travel planner have been represented in the figures, and the analyses for these two figures can be considered as the analyses for the whole model.

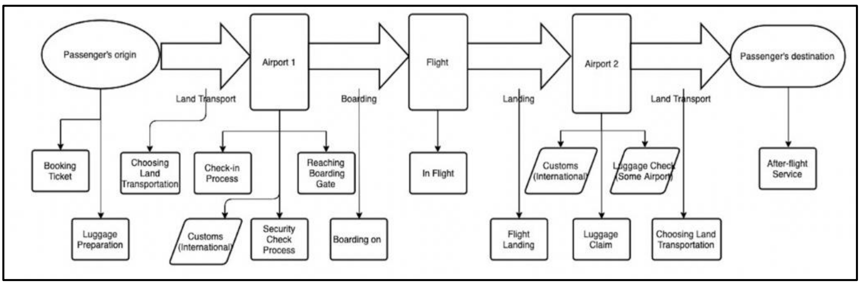

Figure 1: Conceptual model of the digital multi-modal door-to-door travel planner in direct flight route.

This conceptual model introduces the major activities at each travel stage. In the first stage, travellers need to book flight tickets, prepare their luggage, and take suitable land transport to the departure airports. At this stage, disruptions and delays in the travel process may be caused by flight re-schedule, inappropriate luggage, choosing unsuitable land transportation, and land transport delay. The second stage is the main stage in the pre-flight process, including check-in, security check, customs in international travel, and reaching the boarding gates. At this stage, long queues at pre-flight activities, facility technical issues, untimely airport information updates, and other related issues are the main reasons that cause disruptions and delays. However, by linking air transport with land transport, the connectivity of travellers' pre-flight stages can be improved, which contributes to the structure of door-to-door travel. In the third stage, the main activity is the in-flight process, and bad weather conditions and technical issues are the main factors that cause the flight delay in this process. The third stage is essential since it can link the second and fourth stages in the model. It is difficult for travellers to acquire real-time and up-to-date information at this stage in the conventional travel model. However, the door-to-door travel planner can provide real-time travel information and optimum travel recommendations at any stage in the journey, which makes the model unique. In the fourth stage, travellers need to go through customs, claim the luggage, take possible baggage checks, and select suitable land transport for the next stage. At this stage, disruptions and delays may be caused by long queues at customs and luggage claims, facility technical issues, and untimely airport information updates. The fourth stage connects the in-flight stage and the land transport stage, and the connectivity in the entire travel model can be increased accordingly by connecting land transport with air transport. Similar to the first travel stage, the last travel stage is also the land transport stage. At this stage, disruptions and delays may be caused by choosing unsuitable land transport and land transport delays. Since the stages and logic of the conceptual model have been discussed and possible reasons for travel disruptions/ delays have also been identified based on the major activities at each stage, a digital twin model can be effectively built in the next stage.

3.2. Digital twin and Optimum Itinerary using Arena

3.2.1. Model assumption

To improve the accuracy and ensure the results conform to reality, some assumptions have been proposed before conducting the digital twin and simulation.

- Travellers were classified as time-saving travellers and cost-saving travellers.
- Delay/ disruption times and rates were estimated based on the historical data in this route.
- All the data and information used in this study were sourced from the relevant airlines and airports, local governments, transport departments, and relevant organisations.
- In the simulation, time-saving travellers will choose the fastest travel routes in both the ideal and delay/disruption situations, and cost-saving travellers will constantly choose the cheapest travel routes even if these options may take a longer time.
- Travellers can change their travel preferences and choose other travel options anytime during the travel.

3.2.2. Digital twin model

In this section, the digital multi-modal door-to-door travel planner will be digitally twinned and simulated by using the information and data collected from the samples route: from Melbourne, Australia, to Hobart, Australia. The digital twin model covers all the travel stages, including all travel activities and processes. Besides, the modules, stages, activities, and relevant resources in the model can be flexibly modified based on the real travel situations in the journey. The results in this section can be used to support that the developed digital door-to-door travel planner can effectively assist travellers in direct flight travel routes, and it can also prove that the model can optimise travel itineraries for travellers.

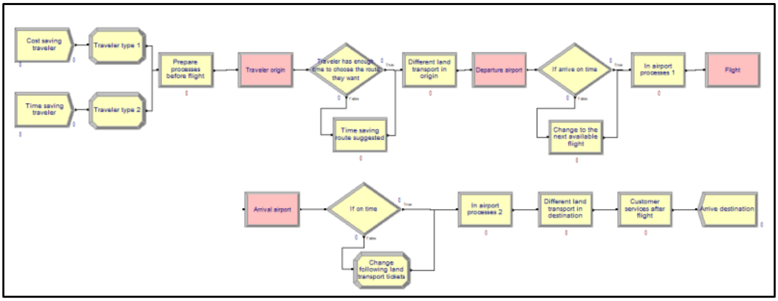

Figure 2: *Arena* frame and flow for the digital multi-modal door-to-door travel planner in direct flight route.

Based on the conceptual model presented in Figure 1, the process flow and activities of the model have been connected and digitised in *Arena*. All the information and data used in this section were sourced from the travel route from Melbourne, Australia, to Hobart, Australia. As shown in Figure 2, all the stages and processes are tightly connected in the model, and the working flow of the model is smooth. This feature enables the model to identify the delays/ disruptions in the entire journey at any way point. Besides, the connections between different travel stages also ensure that travel information and data can be exchanged effectively in the door-to-door travel planner. In the model, firstly, travellers' locations, travel dates, and travel preferences will be collected to generate optimum travel itineraries for travellers choosing. Then, detailed route information and travel suggestions can be presented to travellers. When travellers start to travel, their real-time GPS locations and times will be tracked and compared against the optimum route information provided by the travel planner. If deviations are identified and potential delays/ disruptions may occur, warnings can be provided for travellers, and relevant recommendations and alternative itineraries will be generated for travellers to continue the trip smoothly. Since travellers are tracked and compared continuously, potential delays/ disruptions can be identified in advance, even earlier than airlines/ airports' notifications. Besides, to ensure travellers can complete their travel by following the optimum routes, travellers may need to change their travel at any waypoint under the model's guide in the delay/ disruption scenario. Once delays occur or potential disruptions are identified, travellers will be recommended to change to a faster route to ensure they can catch the next travel stage on time. Moreover, if the model identifies the delay/ disruption also has negative impacts on the following stages, travellers will be suggested to manage and change the following stages accordingly to optimise their journey. Therefore, the digital multi-modal door-to-door travel planner enables travellers to avoid delays/ disruptions in advance and provides optimum alternatives to help them enjoy a smooth travel process.

3.2.3. Simulation results

The digital multi-modal door-to-door travel planner is expected to support travellers to solve all the disruptions and delays that occur in their journey and help travellers achieve effective travel processes. However, whether the model works as expected needs to be assessed. In this section, a sample route, which contains more than one available flight per day, has been used in *Arena* to simulate and examine the functions and logic of the model in actual travel. The model can simulate all possible options to satisfy different types of travellers, including both time-control and cost-control alternatives. More specifically, if a traveller cannot catch the flight on time, the model can provide this traveller with either the next available flight based on the airline's type or the next available flight based on the flight schedule to satisfy different travel preferences. By providing cost-control and time-control options, travellers can select the most suitable alternatives and manage the following travel stages flexibly. The results of this section support that the digital multi-modal door-to-door travel planner can assist travellers by providing flexible and personalised travel options. Besides, the results can prove that the model performs well in actual travel. Thus, the usefulness of the door-to-door travel planner can also be assessed since the model can satisfy all types of travellers with multiple travel options.

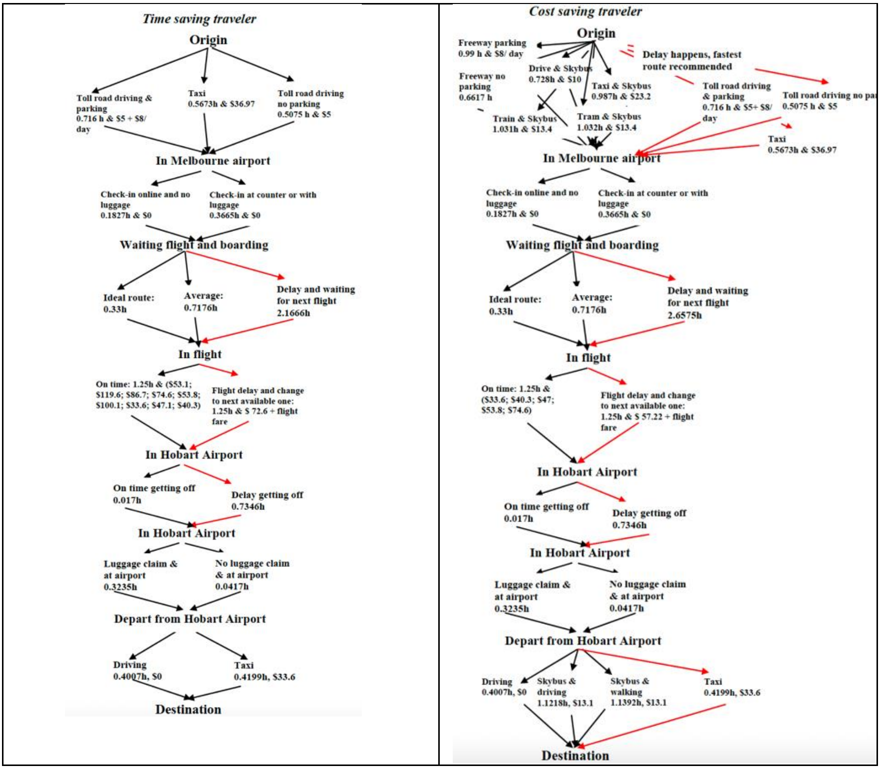

Figure 3: Optimal itinerary for minimum travel time and minimum cost for the sample route.

Figure 3 shows all the simulated travel itineraries for travellers in the sample route, which aims to examine whether the model can provide cost-control and time-control options for travellers. These results can assess whether the model can satisfy all types of travellers in their travel. More specifically, in the model, time-saving travellers will choose the most recent available flights and cost-saving travellers will choose low-cost airlines. During the journey, disruptions and delays may occur at any waypoint, which leads to the different travel options and alternatives shown in the figure. Although time-saving travellers prefer time-control alternatives and cost-saving travellers tend to choose cost-control alternatives in the simulation, the travel planner will generate all types of alternatives when delays/ disruptions occur, which provides opportunities for travellers to change their preferences flexibly. As introduced in the digital twin model, the travel planner will collect travellers' real-time locations and up-to-date transport information at every waypoint in the delay/ disruption situation, and all possible alternative options will be optimised at these waypoints for travellers. In Fig.3, all possible options in the delay/ disruption situation are presented as red branches. Therefore, travellers can change their travel preferences and choose all types of travel itineraries anytime during the journey. In the simulation, all the transport information and travel data are sourced from the sample route. At stage one and stage five, the available land transport in both Melbourne and Hobart includes driving, taxi, and an express coach called "Skybus". Besides, both low-cost flights and full-service flights are available at stage three.

In the sample route, the fastest route for time-saving travellers takes 2.730 hours and costs US$58.14 to us124.68 depending on airfares. In this route, no delay/ disruption occurs, and travellers can catch all the stages on time. However, if potential delay/ disruption is identified and travellers have to change their following routes, the time and cost will change accordingly. For time-saving travellers, since they always choose the fastest itinerates in the trip, they will be suggested to change their flight tickets if a delay/ disruption is identified at the first or second travel stage. For these travellers, the fastest route under the delay/ disruption situation takes 4.566 hours and costs US$111.31 to US$197.34 depending on airfares. If travellers choose other options at land transport stages, the total time and cost will increase.

For cost-saving travellers, the cheapest route for them in the ideal situation takes 2.884 hours and costs US$33.61 to US74.61 depending on airfares to complete the journey. However, once a delay occurs or potential disruption is identified at the first or second travel stages, cost-saving travellers will be suggested to take faster land transportation or change their flight tickets depending on the actual traffic conditions. If travellers can catch the flight by changing to faster land transport means, the cheapest route for cost-saving travellers under the delay/ disruption scenario costs US83.68 to US124.68 depending on airfares and travel time is 3.994 hours. However, travellers may fail to catch the selected flights at Melbourne airport even if they change to faster land transport means, and they have to change to take the next available low-cost flight. In this situation, the cheapest route for cost-saving travellers takes 5.057 hours and costs US95.85 to US136.85 depending on airfares. Besides, the total travel costs and times will vary if travellers choose other options during the journey.

Time-saving travellers and cost-saving travellers are provided with different travel options in different situations, which aims to satisfy their travel preferences and ensure smooth travel processes. According to the simulation results, in both ideal and delay/ disruption situations, cost-saving travellers have to spend more time reducing their travel costs and time-saving travellers always can take the fastest alternative routes to continue their journey. Therefore, the digital multi-modal door-to-door travel planner can generate optimum travel itineraries based on the travel routes, travel times, travel costs, travel preferences, and traffic conditions.

4. Conclusion

The digital multi-modal door-to-door travel planner can be an effective tool to assist modern travellers in their travel processes. By tracking travellers and real-time transport conditions, the travel planner can provide different types of travellers with in-time and optimised travel options. During travel, travellers' actual routes will be compared against the digitised routes provided by the travel planner, which aims to help the travellers complete the journey by following the optimum routes. According to the digital twin and simulation results, the travel planner can generate personalised and optimum itineraries in different situations, which enables travellers to complete the whole trip smoothly. The simulation results can also be used to optimise the trip between Melbourne and Hobart in actual travel. Besides, since the travel planner can identify the potential delay in the whole journey, travellers will have the opportunity to change their routes and avoid disruptions in advance, and the entire travel process will become seamless. Therefore, the digital multi-modal door-to-door travel planner can improve travellers' door-to-door travel experience, and the efficiency of the aviation and travel-related industry can be enhanced accordingly.

The importance of involving digital technology in travel has already been recognised by different aviation companies, however, current digital applications cannot effectively help travellers avoid disruptions and achieve door-to-door travel (Sims et al. 2011; Kluge et al. 2020). With the obvious advantages mentioned in the above sections, the research on the digital multi-modal door-to-door travel planner can resolve the issue and fill the gap between the market needs and the current travel model. Moreover, a high-performance multi-modal door-to-door travel model can bring benefits to economic, social, and political sectors and can positively influence traveller experience and industrial operations (Babić et al. 2022). Thus, the development of the digital travel planner can boost improvements in the travel and transport system, and the assessed travel planner can support modern researchers' propositions of advanced door-to-door travel.

Future work includes developing a D2D App for the digital multi-modal door-to-door travel planner, enabling travellers to use the model on their personal devices in actual travel. Since the logic and functions of the travel planner have been assessed by simulating the sample route, the developed App can be implemented in actual door-to-door travel to optimise the travel itineraries and processes for travellers. More travel routes can be simulated and optimised in the door-to-door travel planner to examine the travel planner's usefulness and help real travellers achieve more effective and seamless door-to-door travel in the next step.

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Safety Incident Classification using Machine Learning Techniques in Airline Industry

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Abstract Safety issues in the airline industry are currently notified using archaic methods despite the technological and mechanical advances in this field. This might include using forms and in-flight personnel to fill out and address any incidents/accidents. The traditional method is very time consuming and human errors can occur. Since the aviation industry was on halt during the COVID-19 pandemic, there are high chances that more incidents could now occur whilst operations begin to transition back to normal. Therefore, a more efficient method for reporting these incidents is required. We suggest a Machine Learning algorithm to automatically classify the incidents based on certain keywords. This will help address safety incidents/accidents more quickly and efficiently and will be a catalyst for change in this outdated system.

Key Words *Safety Incident Classification, Machine Learning, Linear Svc, Data Analysis, Data Science, Aviation Industry.*

1. Introduction

Safety is the most important aspect of flying a plane, far exceeding the advertised luxury and comfortability of travel. Although safety systems and technologies are being developed and integrated regularly, the way they are being reported and addressed is barbaric at best. The current methods of reporting rely on manually input data from pilots or flight personnel who were there during the incident/accident. This makes it highly painstaking, time consuming. There is also a margin for human error which can lead to consequences. In this research paper, we address this issue by implementing an algorithm using machine learning methods, which basically entitles the system to search for keywords in entries and then placing them in their correct genres or factor.
Airline industry has been facing a lot of incidents since its inception. Numerous airlines are trying to record these incidents and analyze the causal factors to come up with strategies to cope up with them. There have been procedures followed before and there have been actions taken in this regard. However, since the COVID-19 pandemic caused the industry to change its working dynamics and in fact go on halt for a certain period of time, it might cause the employees and machinery to cause more incidents that could be harmful. Therefore, machine learning algorithms can play a big role in terms of identifying, classifying and predicting the safety incidents which could help in improvement of overall safety incident procedures.

Robinson and Wu (2015) in their paper discussed about the applications of machine learning, and about how safety trends and safety climates affect the workplace and how it can be categorized to make it easier for an organization to deal with incident and accident classification by asking important questions to build the algorithm around it. Rose and Mavris (2020) discussed the natural language processing methods for clustering, and how natural language can be processed for clustering and analysis of aviation safety incidents using narratives that are available through the Aviation Safety Report System (ASRS), which used specific keywords to get reports from the database this way they were able to pinpoint the useful reports that will be critical in the study. By using metadata-based statical analysis they were able to post-process the groups and identify them (Rose et al., 2020), by doing so they uncovered trends in clustering that do not fall under anomalies in the data which in hand allows them to get more insight from narratives that could be used to classify incidents or accidents.

Safety incidents have been concurrent with aiding the development and improvement of safety and flight standards over the decade. In this research paper, we present a method for classifying these accidents/incidents automatically using Python to implement safety incident classification. We have used certain parameters of datasets with machine learning techniques making it faster and easier to classify the safety incidents in a way that has minimal errors or misclassifications. Moreover, we have implemented multiple methods of classification, which are Random Forest, Linear Support Vector Classifier (SVC), Logistic Regression and Multinomial Naïve Bayes (NB). We will be using these along with datasets we curated from Aviation Safety Reporting System (ASRS).

Our goal is to improve the way of reporting and addressing any safety concerns or issues of any inflight travel or general safety issues and concerns faced on the tarmac. Safety is the most important aspect of flight travel so the ability to greatly improve upon or have a positive effect on maintaining and providing safety for all the people on and off the plane. A successful implementation of this method will provide significant improvement to the way safety issues are reported.

2. Methodology

In order to choose the dataset, we went to the ASRS database to collect incidents spanning in five different areas: human factors, airport, equipment/tooling, weather and staffing. This allowed us to search multiple kinds of incidents at the same time to get a dataset that would be diverse and allow the algorithm to expand the classification scope. We also introduced a dictionary to the algorithm made by professionals in the aviation industry that includes all aviation terminologies, this made the algorithm more accurate, we then coupled this with the stop word dictionary to remove any words that do not contribute to the sentence, we then had to extract 5,000 entries form each class of incidents then merge them into one csv file. This way we had 25,000 entries in the dataset. We split the dataset into training (15,000 entries) and testing (10,000 entries). However, due to limitations of computing resources, we used a random sample of 1,991 entries to train and test the models.

After preparing the data, we moved on to the implementation of the algorithms and finding which model to use. After several trials and tests, we decided to implement the four different Machine Learning algorithms which were: Linear SVC, Multinomial NB, Logistic Regression and Random Forest. By implementing all four we could see and measure the results and accuracy, while also comparing each method using graphs and its accuracy rating. For ease of the readers we give a brief introduction and background on each machine learning method used in the following section.

3. Machine Learning Algorithms

3.1. Random Forest Model

In order to know what class a field or entry belongs to classification must be implemented, which is a very prominent part of machine learning. Random Forest (RF) is a classification technique and one of the most used algorithms in machine learning since it produces accurate results without hyperparameter tuning. These are simple and straightforward, but the problem is they tend to be high variance i.e., they overfit and do not generalize well from a training set to a test set. The Random Forest is an ensemble learning method, with its base learner being a decision tree.

According to a Berkley institute report (Leo Breiman, 2022), "Random Forests grows many classification trees. To classify a new object from an input vector, put the input vector down each of the trees in the forest. Each tree gives a classification, and we say the tree "votes" for that class. The forest chooses the classification having the most votes (over all the trees in the forest)."

A key feature of Random Forests is that they can be used to produce Variable Importance plots. These rank, from top to bottom, the most "important" variables in the data. What is nice about these is, while RFs are not interpretable the way that regression models are, is they are constructed in a different way and can detect things like non-linear relationships. One of the benefits of using RF's is that they are very fast to train and adapt for text data sets when compared with other techniques. Moreover, part of the adaptability is that they are not sensitive to outliers. However, they are quite slow in practice when creating predictions, so a way to make this step quicker would be to reduce the number of trees in the forest, since the more trees added the more the time complexity increases. In order to extract or achieve accurate recommendations for the class using Random Forest model, some implementation steps are required. Having features with predictive power; meaning including little to no garbage values since this will affect the voting and choosing class process. The second is that the trees and predictions need to be uncorrelated or has little to no correlation.

Since, the Random Forest is a classification algorithm that consists of many decisions' trees while building the trees it uses bagging and feature randomness in order to try to create an uncorrelated forest of trees whose prediction committee is more accurate than that of any individual tree. The key to gaining a high level of accuracy is the low correlation in between the models. This is because many relatively uncorrelated trees operating as a committee will outperform any of the individual constituent models. Since there are several trees, they will help shield/protect each other from what individual error may occur, some trees may have wrong results, but many others will be correct.

3.2. Support Vector Machines

Support vector machines (SVM) are considered one of the core machine learning techniques that can help with data classification problems. Support vector machines are a method used for predictions. Supervised learning models with associated learning algorithms aid in classifying and analyzing data. Many people prefer the support vector machine because it produces great accuracy while using less computing power. SVM is a model that may be used for both regression and classification. However, it is extensively employed in categorization goals.

Supervised machine learning is the act of learning and generalizing an input/output map. So, in our use case it would incur inputting a set of excel files containing a narrative column that will contain textual data. The next step would then be categorizing them into their respective classes. However, when the textual data is unlabelled, unsupervised learning can be used. Unsupervised learning uses natural clusters of the data to group them and then map them into the new formed groups. After the step of cleaning and refining the narrative in our document through removal of stop words, the data isthen ready to be processed by a machine learning algorithm to classify the document. The support vector machine algorithm's goal is to find a hyperplane, which is a subspace with a dimension one less or one higher than its space. In an N-dimensional space (where N is defined as the number of features) that will distinctly classify the data points, finding the maximum margin in the plane is the goal for us; the maximum margin being the max distance between the data points of the classes. By maximizing the margin, it allows for future data points to be classified with more accuracy and confidence. There are many methods to separating the data point classes with multiple possible hyperplanes that could be chosen. According to Gandhi R. (2018) "Hyperplanes are decision boundaries that help classify the data points. Data points falling on either side of the hyperplane can be attributed to different classes. Also, the dimension of the hyperplane depends upon the number of features. If the number of input features is 2, then the hyperplane is just a line. If the number of input features is 3, then the hyperplane becomes a two-dimensional plane. It becomes difficult to imagine when the number of features exceeds 3."

Since SVM's only focus is on efficiently computing the similarities of two entries/records, this allows it to not need to represent any examples. This means it has the ability to handle an infinite number of features. SVM does not need the use of aggressive features, especially that they might cause loss of information, so a better utilization would be to improve prediction of classifications by eliminating the need for cross validation, error estimating formulas.

3.3. Logistic Regression

One of the more popular functions utilizing the sick-it Python library, is logistic regression. It is a statistical method for predicting binary classes with the outcomes having only two possible classes, which helps it calculate the probability of an event occurring using equations. Using logistic regression can help assess and calculate the relationship of independent and dependent binary variables.

3.4. Multinomial Naïve Bayes

Multinomial Naïve Bayes (NB) is a learning method that uses natural language processing (NLP); which is an application of computer techniques that try to analyze and synthesize natural language. Using machine learning and natural language processing which would be very efficient and deliver far less errors than if it was done by a human.

The algorithm is based on Bayes theorem, where P(B) represents any prior probability of B and prior A is the prior capability of class A while P(B|A) is any occurrence of predictor B given class A probability, and then attempts to predict a tag in any piece of text, then calculating the probability of the tag for any sample then outputting the tag with the highest probability score. The NB classifier is an assembly of algorithms that follow the same principle where each feature being classified is not related to any of the other features. So, the absence or existence of any feature will have no effect on the use or discarding of any other feature.

With the NB algorithm the more prior entries the more accurate a result will be so working with data sets is not out of the question making it highly scalable and its implementation is simple.

4. Key Findings

After implementing all the algorithms, we then evaluated each one to see which was able to give us the best results with more precision and accuracy. The SVC model in our algorithm was able to successfully classify 1991 data entries with 85% accuracy compared to the other models. Logistic Regression method gave us an 84% accuracy. The Multinomial NB produced 81% accuracy whilst the Random Forest Classifier gave us the lowest percentage of accuracy of 72%. Therefore, we decided to use the SVC algorithm as it produced the highest accuracy rating. Figure 1 depicts the box plot of accuracies of each model. On observing these results, we concluded that coming up with a choice of algorithm for such a dataset could beneficial for the industries that decide to implement such algorithms. It will reduce the time it takes to manually classify them, and it will be more efficient. Theoretically, if given more data entries the accuracy could increase and make it more precise when classifying datasets. This will also improve the safety aspect in the industry since they will be able to classify each incident and find the root cause of it. This could also cut down on expenses that will otherwise be spent on departments or utilities that are not the cause of the incident. Therefore, such algorithms could prove to be very beneficial to airline industry and improve the safety standards of many companies.

	Precision	Recall	F1-Score	support
Airport	0.87	0.89	0.88	595
Human Factors	0.82	0.88	0.85	666
Staffing	0.33	0.05	0.09	37
Equipment/Tooling	0.76	0.21	0.33	61
Weather	0.87	0.89	0.88	632
Accuracy			0.85	1991
Macro average	0.73	0.59	0.61	1991
Weighted average	0.84	0.85	0.84	1991

Table 1: F1-score Precision Prediction.

The results relevant to the Linear SVC model are detailed in Table 1. It is clear that the precision and f1-score to calculate the accuracy for the complete dataset is 0.85 which is 85% making it the most precise prediction we can get with our model and algorithm. Moreover, the heatmap depicted in Figure 2 below shows the number of correct predictions and misclassifications on the testing dataset for Linear SVC model.

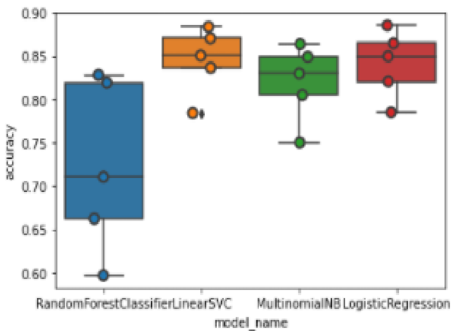

Figure 1: Box Plot of the Accuracy of Each Method.

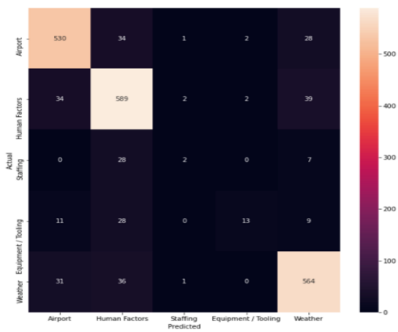

Figure 2: Heat Map of Data.

5. Conclusion

To conclude, we believe the analysis and machine learning model we suggested in this research paper would surely be beneficial to the aviation industry. We tried multiple models to classify the safety incidents. After successfully running and implementing different models using multiple libraries, especially the NLTK techniques for removing stop words or Sklearn for the algorithm implementation we compared and analyzed their performance. It was observed that out of the four models applied the SVC model yielded better performance with 85% accuracy comparing other algorithms. In the future, we hope to improve upon our implementation; by allowing or giving it the ability to accept more records, which would hopefully allow not only for faster and more efficient work but a more accurate result since it is a learning algorithm the more entries the more accuracy we could achieve.

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Advanced Urban Mobility, Electric Vertical Take-off and Landing Aircrafts, Air Transport Policy and Regulation: Creating Sustainable Aviation Through New Aviation Laws and Regulation

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Abstract The premise of Advanced Urban Air Mobility (UAM) in cities worldwide is the provision of an entire ecosystem of silent, safe, sustainable flying transport solutions for passengers and cargo. I am part of a leading Electric Vertical Take-off and Landing Aircraft (EVTOL) producer and operator, Volocopter. The utilisation of "C Space" and available flying corridors within urban environments presents new and exciting challenges for the evolution of Aviation Transport Policy and Regulation and is vital in the quest for the delivery of sustainable aviation solutions. This paper provides a brief overview of the current worldwide regulatory regime and future proposals.

Key Words *EVTOL, Sustainability, Uam-Law, Regulation, Future-Flight.*

1. Introduction

1.1. Objectives

Pollution and congestion are two major roadblocks for mobility, particularly in urban environments. UAM and EVTOL (Electric Vertical Take-off and Landing Aircraft) are offering solutions but have also problems in store that need adequate solutions. This "*new kid on the block*" needs to be accommodated in the lower airspace, between buildings and any other kinds of obstacles and on the ground. Given that sustainability and the reduction of carbon emissions is essential to the provision of modern urban transport mobility, futuristic solutions must be found.

Designing and building up the necessary air and ground infrastructure is an historic challenge. Regulators worldwide have started to develop adequate rules. However, these rules depend very much on the technical development of the aircraft and of the infrastructure. In other words, the current picture of the existing legal framework set out below is just a snapshot on the way to a future that nobody can foresee in detail. However, we are not just witnesses of a challenging development. We, as aviation lawyers, regulators, administrators, academics, inventors, operators, industry sector members, and, simply put, Aviators, are much more than that: We are an integral part of this development.

1.2. Justification

This paper is intended to be a contribution to this development by describing the current UAM/EVTOL legal framework worldwide, explaining why it is so complex, suggest that there is work to be done, and trying to encourage ourselves to go ahead and provide practical futuristic solutions.

2. Methodology

The legal framework for EVTOL and its further development cannot rely on blueprints. It is air transport but with a very local background. Therefore, it can rely on existing aviation regulations only to a very limited extent. The regulators are dependent on the operators and their experience. So, the regulators must give the operators the chance to gain experience by flying. Based on these experiences, the regulators can react and open the framework for more experiences. So, development is a kind of pendulum that swings between operators and regulators. The methodology used in this paper is a reflection of the way in which regulations appear written and developed in a brand new area of aviation law and the role of the aviation lawyers and advisers is to provide contact and guidance to the drafters of forthcoming regulations within the emerging UAM sector.

2.1. Research Approach and Motivation

The author analyses the existing regulations and contributes to their further development by advising Volocopter and discussing the relevant issues with the regulators. Primary research is conducted by the author as part of his ongoing advice to clients and the author is also involved in contributing to new regulation drafts which are being worked on at a high level within such institutions as EASA. The secondary research undertaken by the author on an ongoing basis is probably too long to list within this paper as over the last four years there has been a plethora of published papers, government assessment, think-tank, and management consultant papers, and even a detailed paper prepared by NASA for the prediction of UAM within cities in the USA jurisdiction. The author regularly traces articles in the relevant publications including but not limited to academic papers such as Air and Space Law, Zeitschrift für Luft- und Weltraumrecht, Aerospace Science and Technology, eVTOL News, just to name a few. It is the author's job to keep up to date and ahead of the curb on this "already published" secondary research.

3. Key Findings

3.1. Creating sustainable aviation through new aviation laws and regulations

In May 2021, the European Union Aviation Safety Agency (EASA) announced the results of the first European wide study of citizens' expectations of UAM, showing overwhelming support for the concept but also the need for local authorities to implement their own UAM ecosystems with support and guidance from EASA (EASA, 2021). According to EASA the first certification of piloted passenger-carrying EVTOLs are expected as early as 2024 (EASA, 2021). The on-line quantitative survey polled 4,000 citizens in six European urban areas. This was complemented by more than 40 qualitative interviews, as well as a noise simulation test. The survey showed that 83% of respondents have a positive initial attitude towards UAM, with 71% ready to try out UAM services. Public safety, via, police and ambulance services and UAM, such in emergencies or for medical transportation received strong support (EASA, 2021). It is worth noting that there are already incredibly advanced drone medical supply companies distributing medicine to remote areas worldwide together with disaster relief whether it be for the floods in Germany (BBK, 2021) or war on several continents. This public service function is popular and readily understood. EASA has used the study results to prepare an impact assessment and regulatory proposal for Urban Air Mobility in Europe.

"*We are not planning to certify the entire eco-system local decisions need to be taken by local actors*," Patrick Ky, EASA Executive Director Patrick Ky, introducing the results of the survey at a press conference on 19 May 2021. "*So what we intend to do is certify the aircraft to provide our views on the constraints on the operational environments in which this aircraft is certified to operate safely and then it will be up to local authorities to take those constraints into account for certifying the vertiports and landing sites also the highways.*"

The study concluded that all regulatory authorities must work together at all levels and that citizens do not differentiate between different levels of authorities. All local and national stakeholders indicated they clearly wanted to take a role in the introduction of UAM; they expected clear guidance from European level but they also wanted to be involved in concrete local decisions, for example involving routes, traffic frequencies and the location of Vertiports so they could create local buy-in. Vertiports are a new concept akin to Heliports, but different in that they are relatively cheap to build with high end materials and customer experience, with simple mixed online check-in followed by face to face contact, positioned on top of high urban buildings or at ground level near urban sites of interest. For example the "Voloport" which has been designed by partners working with Volocoptor in Downtown Singapore (Volocopter_Whitepaper_Singapore-Roadmap, 2022).

With this sentiment in mind, this paper sets out a short overview of the current worldwide regulation of the UAM and an explanation of the same and will provide a sounding board for the desire for all actors to work together to deliver UAM in a safe sustainable way.

3.2. Core regulatory approvals in most jurisdictions

This new type of lightweight aircraft utilises electric power to take off, hover, and land vertically, and has emerged as a critical component in addressing modern transportation needs in and around cities. EVTOLs offer a sustainable transportation solution for moving passengers and cargo in urban areas, between 60 to 200 miles, alleviating ground transportation congestion and reducing carbon emissions. In some jurisdictions commercially-operating EVTOLs are anticipated imminently, as soon as 2024 (Regulation and Certification 2022).

In this paper, I will attempt to summarise the current applicable legal and regulatory requirements for EVTOLs, with a particular focus on certification, as well as a preview of the broader issues that will need to be addressed to bring EVTOLs from concept to reality and give specific examples of processes we encounter on behalf of our clients, but also allude to public concepts of safety. Safety is paramount for new technology and EVTOL producers such as Volocoptor aim to provide a produce that has a safety quotient well in advance of that expected for normal passenger aircraft.

3.3. Three core regulatory approvals in most jurisdictions for EVTOLS

For EVTOLs to be certified to fly commercially for reward, three core aviation regulatory approvals will be required in most jurisdictions: (i) type certification, (ii) production certification, and (iii) operational certification by operational authorities.

Type certifications are the regulatory approval of the airworthiness of a particular manufacturing design (type design) and are the first step for commercialisation of any EVTOL. Many companies are currently in this phase of their business plans, as they design their EVTOL aircraft and pursue a type certificate (Vertical 2022). Production certification allows for mass production of a particular EVTOL and is granted when a manufacturer can demonstrate that it can produce aircraft that will meet the standards of a type certificate. Finally, to operate EVTOLs commercially by transporting passengers or cargo, additional operational requirements and authorisations for commercial operations are required.

These government approvals are in some ways akin to requirements for traditional commercial aircraft used in passenger and cargo operations. However, civil aviation authorities worldwide are in the process of adapting regulatory frameworks to account for fundamental differences in EVTOL technology and operations as compared to traditional aircraft. Future EVTOL applications will include autonomous operations, without pilots, which present many of the same regulatory challenges that unmanned aircraft systems (UAS or "drones") have been grappling with in recent years. We will provide a distinction between piloted EVTOL presently and drones in the next sections, but automation and eventually autonomy will possibly be delivered in the future.

3.4. United States Approach to Regulation of EVTOL/UAM by the Federal Aviation Administration (FAA)

The FAA takes the approach that it will use existing regulations and then adapt them to encompass the new EVTOL technology, although in reality the FAA is working on several new regulations (Vertical 2022). EASA takes a different approach and is writing new regulation in conjunction with feedback from EVTOL manufacturers, operators and providers (Vertical 2022). The FAA is presently working to adapt existing aviation regulations to accommodate this new technology (FAA Drones).

The first step in obtaining a type certificate for an EVTOL involves airworthiness approval of the aircraft and its components according to its type design. To address EVTOL type certification, the FAA applies one of two existing certification processes in 14 C.F.R. Part 21.17(a) and (b) (see also Baker McKenzie, Type Certification 2022).. Part 21.17 (a) involves the designation of applicable airworthiness standards when the aircraft closely matches the characteristics of a particular airplane or rotorcraft class, along with special conditions to address any differences. Part 21.17(b) is used for special classes of aircraft, and the FAA will apply airworthiness requirements derived from other regulations as appropriate, in addition to other airworthiness criteria that the FAA may find to provide an equivalent level of safety to existing airworthiness requirements. The FAA is currently working on draft policy and guidance for EVTOL type certification and has indicated that it is deciding whether the process under Part 21.17(a), using the airworthiness standards for Normal Category Airplanes under 14 C.F.R. Part 23, or the process under Part 21.17(b) will apply to EVTOLs.

Once a type certificate is issued, EVTOL manufacturers will need to obtain a FAA Production Certificate, which is an approval to manufacture the EVTOL product under an FAA approved design and requires that a manufacturer demonstrate its ability to produce the aircraft to the same standards.

Lastly for Operational Certification, companies wishing to operate EVTOLs commercially must also obtain an Air Carrier Certificate from the FAA under 14 C.F.R. Part 135, which carries additional safety, maintenance, performance, and operational requirements.

Note that EVTOL operators must also obtain economic authority from the Federal Department of Transportation DOT to operate commercially and will be subject to associated US ownership and control requirements.

3.5. European Union Approach to EVTOL/UAM Regulation by EASA

In contrast to the approach adopted by the FAA in relying on existing regulations, EASA has and is developing draft regulations and a new EVTOL certification framework through a series of key building blocks. The result is a new set of rules, with incorporation of existing regulations where possible.

The first building block to EASA's approach to certification was in July 2019 proposed Special Condition for Small-Category VTOL Aircraft (SVTOL). This contained the certification framework for manufacturers to start developing innovated air taxi EVTOL vehicles. In May 2020, EASA published its first set of means of compliance for the SVTOL. In May 2021, EASA published phase two of the SVTOL (EASA, Means of Compliance 2021). The second block proposed certification requirements for electric and hybrid propulsion systems, and the third publication of means of compliance with the SVTOL was published on 29 June 2022 following public consultation (EASA, Special Condition 2022).

EASA's SVTOL means of compliance are intended to provide clarity to EVTOL manufacturers and investors on the airworthiness standards for issuing EVTOL type certificates and how EASA will address the unique characteristics these aircraft. Like the FAA, safety remains the prime concern for EASA. With its draft regulations, EASA aims to develop a "one size fits all" approach to ensure that all EVTOL designs accomplish a comparable safety level. While EASA is still developing the SVTOL, EVTOL companies are already proceeding in obtaining their certification basis under SVTOL and this process is being conducted through Certification Review Items, which are a formal administrative means for EASA to record certification subjects and interpretations throughout a certification project. EASA also requires companies manufacturing type certificated products to obtain an EASA Production Organisation Approval.

EVTOL operators must obtain an Air Operator Certificate (AOC) on the basis of Commission Regulation (EU)No 965/2012, which outlines EASA's technical requirements and administrative procedures for airline certification. However, current EASA AOC requirements are tailored to existing types of aircraft and EVTOLs. Additionally, operational authorisations are currently handled by each EU Member State. EASA is therefore conducting a rulemaking process under a Notice of Proposed Amendment NPA to address the integration of EVTOLs into European airspace.

The first regulatory proposal, a Notice of Proposed Amendment (NPA 2022-06) was published by EASA in June 2022 and is a comprehensive regulatory framework to address new operational and mobility concepts and it follows the standard EU rulemaking process (EASA, 2022 and EASA NPA 2022).

Similar to the FAA's decisions on EVTOL type certification, EASA's decisions around the SVTOL will be an important factor in determining the rules that will ultimately apply to other regulatory issues critical to the commercial deployment of EVTOLs, such as operations, pilots, and infrastructure.

3.6. Distinction and overlap between EVTOL and Drones

In the context of urban air mobility, EVTOL is typically used to refer to aircraft intended to carry human passengers or significant amounts of cargo. Most of these aircraft are being designed with high levels of autonomy, although they may be certified to fly only with a human pilot on board.

The ability to conduct unpiloted flight testing is an advantage in the development process, as it allows companies to test and perform Research and Development through various designs and explore certain flight regimes without risking the life of a human test pilot. However, while most EVTOLs are functionally drones, they would not be described as such if they are certified for conventionally piloted flight. Also, in order to obtain early certification it is necessary to have piloted flights for EVTOLs in the immediate short term for reasons of public safety and public reassurance.

3.7. Overview of Unmanned Aircraft System (UAS) Regulation in Europe

The European Commission issued a new regulation commencing 31 December 2020 consisting of two delegated regulations on the systems of unmanned aircraft, drones or UAS and on their rules and procedures for use (EU, 2020). These are the Delegated Regulation (EU) 2019/945 of the Commission of 12 March 2019 and Implementing Regulation (EU) 2019/947 of the Commission of 24 May 2019.

In a similar vein to the ICAO Model Regulations, the EU Regulations seek to target the heaviest regulatory burden at the areas of highest perceived risk while maintaining a relatively light touch approach to those operations considered lower risk. It does this by the separation of operations into three categories:

1. Open-low-risk operations not requiring authorisation or declaration before flight.
2. Specific-medium-risk operation requiring authorisation by the competent authority pre-flight, taking into account the mitigation measures identified in an operational risk assessment; or a pre-flight declaration for certain standard scenarios; or when. The operator holds a light UAS operator certificate with the appropriate privileges; or under the auspices of a model aircraft club/association.
3. Certified-high-risk operation requiring a certification process consisting of: (i) the certification of the UAS, (ii) a licenced remote pilot and (iii) an operator approved by the national competent authority.

The framework for operations in the "Certified" category is currently under development.

3.8. Summary of USA/FAA Regulation and European/EASA Regulation

It can be seen that there are two different approaches to the regulation of the nascent UAM industry, but both the FAA and EASA have indicated an openness to work closely with the industry operators, manufactures and providers and lawyers to produce new and appropriate regulation and this is an extremely encouraging and ongoing process.

3.9. Ongoing Process

Beyond the scope of this paper, it is important to note that the ongoing process for the provision of a UAM superstructure of new aviation laws and regulation involves dialogue not only between regulators and EVTOL providers and legal advisors but also a myriad of local and international stakeholders. For instance as is widely reported, the city of Paris intends to showcase the Volocopter flying EVTOL as part of the celebration for the Paris Olympics 2024 (Countdown 2022). It goes without saying that the relevant stakeholders who are in negotiation with the provider and operator of the EVTOL, Volocopter, are numerous and interconnected in their desire to have a safe fully licensed and operational EVTOL full certified by the time of the summer Olympics in less than 2 years' time. The actors involved in delivering this project include the National Civil Aviation Authority, the Airport Authority, the Mayor of Paris, the National Government of France, the planning authorities of Paris, security services, the Police Authority, EASA, the Olympic Committee, the provider of "Vertiports" which will be renamed "Voloports", local noise enforcement officers, the RATP Public Transport Authority of Paris and other stakeholders. It can be seen therefore that creating sustainable aviation through new aviation laws and regulation is a complex but nevertheless stimulating process with a distinct goal to be delivered.

4. Conclusion

EVTOL flight and Advanced Urban Air Mobility is the future of urban aviation. Its premise is a form of sustainable carbon neutral aviation and part of the ecosystem which is proposed involves the adaption, rewriting and constant updating of aviation policy and regulation. New aviation law will be a vital component to the provision of this. In addition, other stakeholders such as national and local governments, planning authorities and regulatory disciplines across the board of public law and government will be part of the process of delivery. The above overview provides a launchpad for discussion and engagement between these stakeholders and exciting effort and work lies ahead for all involved.

5. Acknowledgements

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The Future of Aviation with the Blockchain

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Abstract Blockchain is a peer-to-peer electronic data transfer technology, first implemented as Bitcoin, a digital payment system between two parties without relying on any intermediate party. Blockchain offers a completely secure, decentralised, transparent and auditable system of data storage and value transfer. This study proposes a novel method of issuing flight tickets as non-fungible tokens (NFT) on the Blockchain. Flight ticket NFT's yielded an efficient mechanism for provable ownership of an asset without intervention of a third-party to eliminate ticket fraud, identity theft, overbooking and data compromise**.**

Key Words: *Aviation, Blockchain, Security, Auditability, Tokenization*.

1. Introduction

The aviation industry relies heavily on the use of technology and data to fulfil its operations. The technological involvement exposes the aviation industry to a plethora of security vulnerabilities and other inefficiencies such as data silos, passenger and personnel data privacy, fraudulent activity, that are a major cause of concern when it comes to enhancement of aviation operations (Alabsi, 2021). The paper discusses the use of Blockchain technology in a wide array of aviation related processes and deliverables of Blockchain that can lead to a major contribution in the technological advancement of the aviation industry.

1.1. Overview of Blockchain network architecture

Bitcoin is a peer-to-peer electronic asset transfer technology (Nakamoto, 2008). Nakamoto, the inventor of Bitcoin technology called it a paper-to-peer electronic cash system, capable of replacing the current Fiat monetary system and transforming it into a much more robust method of value exchange (Nakamoto, 2008). The technology behind the Bitcoin was later termed as Blockchain, which is essentially a distributed public ledger in which data is stored as timestamped transactions into a chain of 'blocks' tied together by hashes of each block in the subsequent one (Zheng, 2018). Blockchain technology proves to be a system which is highly secure due to its nature of being decentralised, meaning that even if one or many participants in the network (nodes) are compromised, the data is still present in many others (Monrat, 2019). Blockchain is completely transparent and auditable, as it is a public ledger of transactions which anyone can access and verify due to digital signatures (Monrat, 2019). Blockchain network is secured by the means of a consensus protocol, where every transaction that is included in a block (mined) is verified by all the participating nodes in the network and if the transaction is deemed invalid, it is not included in the block. The consensus protocol ensures only the valid chain propagates throughout the network (Nakamoto, 2008). The consensus protocol introduced in the Bitcoin paper is called proof of work, in this protocol, the node that is responsible for including transactions in the block (miner) must expend computing resources to solve a puzzle and find the solution called "nonce" and present it as a proof to the other nodes, the other nodes can then verify the solution which ensures only valid transactions are present in the block. The economic incentive to keep the chain valid lies in only mining the valid transactions and reaching a solution to the puzzle because if any invalid transaction is mined, the other nodes simply disregard the block and the resources that are expended by the miner go to total waste (Nakamoto, 2008).

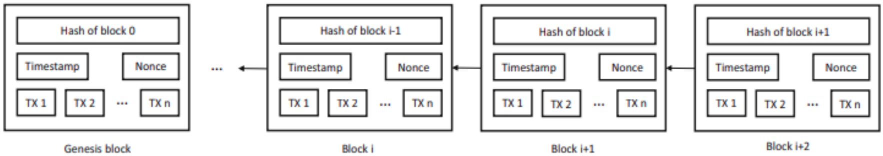

Figure 1: Blockchain Architecture (Zheng, 2018).

Blockchain technology consists of several layers of protocols that make up its infrastructure. The first layer is of course the internet layer, the other more prominent layer is the actual decentralised network layer which is essentially the Blockchain. The next layer is the application layer of the Blockchain which comprises autonomous programs called "Smart Contract" that reside and execute on the Blockchain itself and these programs are the backbone of decentralised applications (Dapps) that allow the users to interact with the Blockchain (Kolvart, 2016). Smart contracts differ from conventional contracts in the sense that they are executed onto the Blockchain, can never be changed and provide much more functionality than simple contracts like automated execution of business logic with respect to some pre-specified conditions, holding funds which can act as escrow (Hewa, 2021). Smart contracts have become vastly popular due to their profound utility in a wide array of real-world applications that could benefit from them. Applications that require unconventional security and enhanced data integrity are increasingly using smart contracts, transforming centralised applications to decentralised applications (Dapps). Constant improvements to smart contracts made by researchers and developers around the world as it realises the obvious benefits that can be achieved from this technology.

1.2. Impact of Blockchain on aviation

Blockchain technology has proven its merit in numerous applications ranging from cryptocurrencies, supply chain, finance, governance, manufacturing of goods, voting, public records and many others (Monrat, 2019). Blockchain has greatly improved the organisational performance by means of trust and transparency never before achieved in a manner as now (Ali, 2020). Blockchain has revolutionised a large set of industries by introducing unprecedented benefits for business processes (Li, 2021). Blockchain technology has continuously been utilised in the logistics and supply chain area. Aviation is a ripe field where Blockchain can provide excellent deliverables. Notwithstanding, research connected with blockchain applications in aviation is in its earliest stages. This research gives noteworthy knowledge into the determinants of blockchain inclusion in the aviation business. The technology adoption model is applied to make sense of the aviation business' expectation to embrace blockchain technology for likely applications and future enhancements (Li, 2021). Research uncovers that tracking and tracing, digitised administration, air traffic management, regulations and industry guidelines, and mechanical upgrades and enhancement on productivity apply a positive effect on aim to utilise blockchain (Li, 2021). Additionally, the aircraft maintenance and spare parts market can benefit from the use of Blockchain as well (Ho, 2021).

2. Literature Review

The following section highlights the literature review performed by the research team. The literature review elaborated in this paper is critical to the proposed use-case and the technologies used to serve the development ensure the most secure and proper implementation in the field. The following technologies were utilised by the researchers to achieve the desired goal of this study.

2.1. Blockchain

Blockchain is a decentralised network of servers that share an immutable public ledger (Holotescu, 2018). The public ledger is designed as a data-structure called "blocks" where each block contains several transactions that are stored along with the block timestamp, hash of the transactions and each block has the hash of the previous block (parent) in it and so forth (Nofer, 2017). The first block is known as the "genesis block" and all the blocks are cryptographically linked together using SHA-256 hashes (Nakamoto, 2008). The exact copy of this chain of blocks is distributed among all the participants in the network called "nodes". This robust architecture ensures that the Blockchain remains true in the sense that no factor either from the inside such as data corruption or outside like a malicious actor can influence the ledger in a manner that renders the data invalid or erased (Nofer, 2017). The nodes that create blocks are called miners and are rewarded with a certain number of tokens for mining a block. The Blockchain ledger is secured additionally with a consensus protocol that ensures that only valid transactions are recorded on the Blockchain and that all the nodes have the valid chain (Nofer, 2017). The consensus protocol that was implemented by Nakamoto (2009) is known as "proof of work" (Nakamoto, 2008). The proof work is a consensus protocol that works as follows: (i) The miner collects the transactions from the pool of awaiting un-processed transactions, processes them and includes them into a block. (ii) The transactions are hashed using the SHA-256 algorithm. (iii.) The solution to the proof of work puzzle called a "nonce" is found by repeatedly hashing the contents of the block until a hash is reached starting with a specified number of zeros (Nakamoto, 2008). (iv.) The nonce is added to the block and the block is broadcasted to the entire Blockchain network. The proof of work is a robust mechanism of ensuring the security of the network because it is exponentially difficult to find the nonce and once the block is hashed along with the nonce the required proof can be validated by the other nodes in constant time. This also creates economic incentive for the miner to always work to find the nonce and the attacker if capable of changing the content of a block is able to perform the proof of work for that particular block, they still have to redo the proof of work for all the following blocks to out-compete the other valid chains that other miners are producing. This economic protection of the network keeps it resilient against the attackers because if the attacker is slow in building the invalid chain, the true chain will catch up and replace the malicious chain, rendering all the resources spent by the attacker completely null (Nakamoto, 2008).

There exist three types of Blockchains, (i.) **Public Blockchain** (ii.) **Private Blockchain** (iii.) **Permissioned Blockchain**. The Public Blockchain, as discussed in detail previously in this paper in section 1.1, is a Blockchain network that is disseminated across the globe and anyone can perform transactions or join as a node. Private Blockchain is a network that is confined to a single organisation. Only the nodes in that organisation can join the network and the data stays within. A Permissioned Blockchain is a private network, but it allows for other external parties to take part in the network as nodes or transacting parties. Both private and permissioned Blockchains do not run-on proof of work consensus protocol, rather they have custom consensus protocol based on authorization and voting and do not have miners as the transactions are simply recorded by all the parties as is after the consensus on the validity of the transaction is agreed upon.

2.2. Digital Signature Algorithm (ECDSA)

The algorithm "Elliptic Curve Digital Signature Algorithm (ECDSA)" is used for digitally signing the transactions and verification of digital signatures. The Elliptic Curve Digital Signature Algorithm (ECDSA) is a Digital Signature Algorithm (DSA) which uses keys based on Elliptic Curve Cryptography (ECC) (Johnson, 2001). The signature uses "private key" to sign the hash of the data and uses "public key" to verify the signature in combination with the hash of the data that was signed (Johnson, 2001).

Parameter	**Description**
CURVE	the elliptic curve field and equation used
G	elliptic curve base point, a point on the curve that generates a subgroup of large prime order n
n	integer order of G, means that $n \times G = O$, where O is the identity element.
d_A	the private key (randomly selected)
Q_A	the public key $d_A \times G$ (calculated by elliptic curve)
m	the message to send

Table 1: ECDSA Signature Parameters (Wikipedia, 2022).

The signature is a set of strings that proves a signing operation. A signature is mathematically derived from the hash of data to be signed and the private key (Santra, 2016). The resultant of the ECDSA algorithm are two numbers, 'r' and 's'. To determine whether the digital signature is genuine, the public key and hash are fed to the ECDSA algorithm, and it mathematically proves the digital signature without knowledge of the private key.

Figure 2: Digital Signature Value.

Figure 2 shows the 'r' and 's' values of the digital signature generated after using the ECDSA algorithm along with the signature timestamp in 'Unix' format, which can then later be converted to UTC or other formats as per requirement. The method for verification requires that the signature, public key and hash of the data be provided. The method outputs the result as either "true" or "false" after running the ECDSA algorithm.

2.3. AES Encryption

The AES algorithm Encrypts data blocks of 128 bits in rounds of 10, 12 and 14 with respect to the key size (Mahajan, 2013). This algorithm was chosen by NIST as a replacement for the previous DES algorithm (Mahajan, 2013). A private key is used to cryptographically lock the data and turn it into a string of pseudorandom bits that cannot be interpreted by anyone. Since Blockchain is a public ledger that is accessible to everyone in the world, the transactions can be seen by anyone and sabotage the privacy and security of the system. To alleviate the said problem and vulnerability, AES encryption suits best to mask all the on-chain data into a pseudo-random string which is only to be decrypted by means of private key that was used to encrypt the data (Mahajan, 2013).

2.4. Tokenization

Tokenization refers to the process of converting an asset either tangible or intangible into a digital medium which can be traded or transferred (Tian, 2020). A token can represent a certain value in a complete asset that acts as a share (Tian, 2020). Tokens are a key deliverable of Blockchain technology and was the pioneer use case of the Blockchain technology proposed by Nakamoto(2009) Through tokenization, an asset can be divided into share each representing an equal value in the case of fungible tokens (Tian, 2020) or in the case of non-fungible tokens, the asset is simply digitised in a manner that it cannot be broken down and cannot be traded as an equal to any other token (Tian, 2020). We can divide tokens into two categories, a utility token and a security token (Tian, 2020). A utility token is used mainly for offering services or products by the party that is issuing them, usually through an Initial Coin Offering (ICO), an event where the investors are issued tokens just like an Initial Public Offering in a stock exchange market albeit it can be online rather than in person. The holder of a utility token can trade their token for a service and it provides an excellent opportunity for the issuing party to perform impeccable governance such as ensuring a one-time offer per customer (Tian, 2020). A security token on the other hand is analogous to a share of a company, these must be backed by an asset such as the financial value of the company or project issuing them (Tian, 2020).

Non-fungible tokens (NFT) are usually associated with collectible assets such as digital art, music etc. They offer an excellent way of managing ownership of assets due to the immutable trail of the ownership records on the Blockchain. The creator of an NFT can also earn royalties through the subsequent sales of the NFT. NFT's are set to revolutionise the creator economy, identity and governance by way of easing the process of selling an asset and provable ownership.

3. Methodology

The research team studied the already implemented use-cases of Blockchain in the aviation industry and foreseeable implementations that could profoundly affect the aviation business in a positive manner. There exists a number of convergent uses of Blockchain around the world in numerous industries like supply chain, finance, healthcare where the well-thought integration of Blockchain has led to unprecedented outcomes and allowed for robust operational fluidity and strengthening of business processes. This study proposes a novel mechanism of tokenization of airline tickets along with an additional set of use cases that could be beneficial to the aviation industry such as tokenization of air miles. This paper reviews other highly advanced techniques to enhance the security of the aviation industry. By using technologies usually best coupled with the Blockchain, such as digital signatures that are cryptographically generated using algorithms that ensure anonymous proof of ownership and encryption standards that allow for storing sensitive data such as passenger information, aircraft information, and financial data on the public Blockchain.

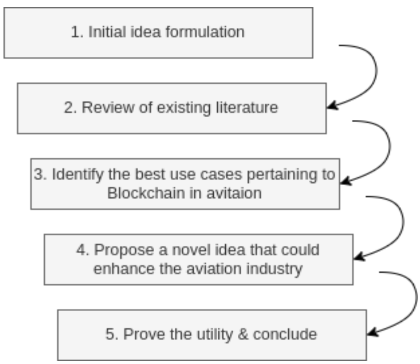

Figure 3: Research methodology.

Figure 3 illustrates the set of steps followed by the research team to study the available literature about aviation and Blockchain. The research team formed the initial idea based on the observed problem of the airline ticketing system and aimed at a solution viable enough to be implementable in the vast aviation industry. The team then began work on the collection and careful review of the existing literature to grasp the progress in the subject and to build a foundation to base their work upon. Then the primary objective was to identify the exact use-case and implementation details that could greatly benefit the aviation industry without much disruption to the existing procedures and enhance the economy. The team worked on the idea based on the performed research and came up with the solution of issuing flight tickets as NFT's to eliminate the overall inefficiencies and introduce greater utility for both the passengers and the airlines. The system proposed in the study proves to be a fit use-case for the aviation industry and can also be built upon to offer further deliverables such as issuing air miles as NFT's.

4. Key Findings

This part highlights the key findings of the research team in proposing the novel idea of "flight ticket tokenization" that could largely enhance the aviation industry processes as well as enhance the passenger and personnel experience by creating a non-fungible token of the ticket that is being sold to the passenger, thereby creating an immutable record of the ownership of the ticket. In addition, the research team collected previous research in the field of aviation to achieve a greater understanding of the scope of the subject. The section also mentions some of the projects that work on a similar field in utilising the Blockchain technology in one way or the other such as payments, supply chain, data security and identity.

4.1. Blockchain in Aviation

Figure 4: Blockchain use-cases in aviation (Li, 2021).

Figure 4 shows a matrix of the identified use-cases that Blockchain adoption can serve pertaining to the aviation industry.

Blockchain allows for the ability to create smart contracts which are electronic agreements that execute by themselves upon a set of predefined rules. The use of smart contracts can be adopted in airline transactions such as the billing among airlines, the billing between travel agencies and airlines, the sale of travel insurance, the determination of loyalty settlements and the payment of airport and authority fees and taxes. Using Blockchain and digital wallets, the process of identity management and proof is separated from third-party systems as the identity information can simply reside in the wallet of the individuals and presented with a digital signature at the time of verification (Jacobovitz, 2016). Throughout its lifecycle, aircrafts go through numerous maintenance overhauls and part replacement (Ho, 2021). This makes the tracking and tracing of parts and maintenance logs a very tiresome and inefficient process (Li, 2021). For this reason, an immutable record which lists the maintenance history of the aircraft in a digital manner would surely provide tremendous value to the entire industry. The aircraft's entire history could be gathered from a single source of truth that proves the authenticity using the digital signature trail of the personnel or the companies that worked on the aircraft. According to the resolution 753 of International Air Transport Association (IATA), the mishandling of passenger luggage is one of the top priorities when trying to enhance the passenger experience in aviation tourism (Muruganantham, 2020). Blockchain allows for the reliable and immutable tracking of the location and status of passenger luggage and cargo as the trail is such as of supply chain. As such, blockchain can aid in enhancing transparency and visibility which will allow authorities and passengers to always locate their luggage easily across the supply chain.

Tourism accounted for 5.5% of global GDP and 272 million jobs, making it one of the most important industries in the world in 2019 (Erol, 2022). This huge turnover is a boon for the economy and a considerable population of the world that have jobs because of it but also makes the aviation industry a high frequency carbon emission industry which outputs around 2% of global CO2 emissions (Valdés, 2021). AirCarbon is a carbon exchange launched in Singapore in 2019, that tokenizes existing and certified carbon credits to enhance price transparency and liquidity and to support commodification of carbon projects (George, 2021). Blockchain can be used for efficient tracking of carbon credits and sustainable approaches to utilising the technology across the aviation space.

4.2. Tokenization of flight tickets

Blockchain enables the tokenization of assets in the form of non-fungible and fungible tokens. In this study we propose a novel method of issuing tickets to passengers in the form of "tokens". The use of smart contracts would enable the issuance of ticket tokens in an automated manner. Non-fungible (NFT) token of ticket allows the bearer to efficiently prove the ownership and prevents malicious ticket fraud. An NFT is directly transferred to the person's wallet through the peer-to-peer Blockchain network without any intermediary party. The wallet is secured with the private key of the individual, thus making the process of ticket verification independent of any underlying system.

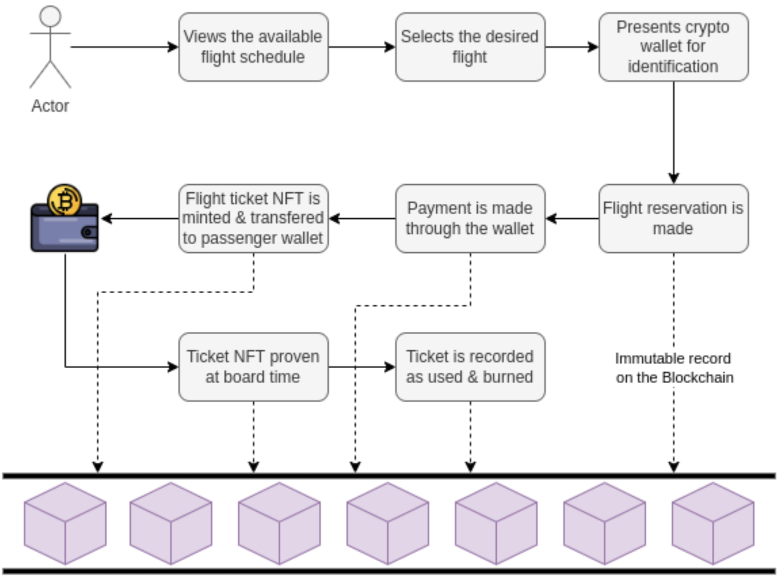

Figure 5: Flight ticket's lifecycle as an NFT.

Figure 5 illustrates the whole operation of issuing the flight ticket as an NFT and depicts in detail the steps that would be undertaken for the entire lifecycle. The passenger will identify themselves with a Blockchain wallet, the payment of the flight ticket will be made through the same wallet. After confirmation of the payment, the NFT of the flight ticket will be minted and transferred to the passenger's Blockchain wallet as an NFT. This whole process will be purely automated as per the smart contract and all the activity will be permanently recorded on the Blockchain ledger, later to be audited by any authority as needed.

5. Conclusion

This paper highlights the characteristics of Blockchain technology. The architecture of the Blockchain technology is discussed in detail along with its most prevalent use-cases. The Blockchain shows great merit in providing a decentralised, more secure, transparent, auditable and trustless system where records of all kinds can reside in a permanent manner without the risk of being compromised in any way. Blockchain provides a way for trust less applications using smart contracts that allow for building applications that work by setting a predefined set of conditions and executing certain logic when they are met, without relying on any intermediate third party. Smart contracts have greatly revolutionised the finance, supply chain, logistics, healthcare and many other industries. The researchers in this study performed an in-depth review of the impacts of Blockchain in the aviation industry such as identity management, flight data, booking data, aircraft parts tracing, aircraft maintenance and environmental factors e.g., carbon emissions. The study proposes a novel method of issuing flight tickets to passengers, as NFTs that are transferred to their wallet directly. The passengers can prove the ownership and authenticity of the ticket directly without needing any third-party. This use-case ensures the elimination of incidents like ticket fraud, overbooking, identity fraud, passenger data compromise and enhances the whole process and passenger experience.

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Airports Ground Operation Resource Optimisation Based on Arrival Time Prediction using Machine Learning

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Abstract Managing aircraft turnaround is a complex process due to various factors, including passengers handling. Airport ground handling, resource planning and optimal manpower and equipment utilisation are some of the cost-cutting strategies, particularly for airlines and ground handling service teams. Scheduled aircraft arrival and departure times are a critical aspect in the entire ground management and passenger handling process. This study focuses on exploring the use of machine learning-based prediction techniques to enhance prediction of aircraft arrival time and ground resources. We developed a machine learning-based model that can estimate the next arrival time of an aircraft departing from airport based on its departure time from the same airport with a root mean square error of 8 minutes in normal weather conditions. Our findings suggest that machine learning-based approaches can be used to predict the number of actual flight movements per hour well in advance in order to optimise constrained airport resources.

Key Words: *Ground Operations, Airports, Machine Learning, Arrival time*, *Prediction, Ground resources.*

1. Introduction

Airport capacity and resource constraints on the ground play a critical role in scheduled flight delays, resulting in unsatisfied consumers and higher expenditures for airlines. A variety of innovative technical solutions have been developed in recent years to improve ground operations effectiveness and minimize delays. Airlines are continuously attempting to enhance operational efficiency by concentrating primarily on measures to reduce in-flight fuel use and associated costs. Another area where operations may be optimised when considering total flight operations is on-ground resource management. Typical ground operations and turnaround processes in hub airports when an airline or ground handling team offers limited ground resources to several aircraft simultaneously (AllThingsOnTime, 2022).

Turnaround processes and turnaround times (TATs) can be affected by a variety of factors, including airline business strategy, onboard service, aircraft size and the airports and routes served. Low-cost carriers (LCCs) and those that primarily operate point-to-point networks are more likely to have shorter average TATs than full-service airlines that use hub-and-spoke systems. Short TATs are an important component of the low-cost business model, and they are meant to maximise aircraft use. Full-service carriers may have longer TATs since their schedules are often designed to offer connections at a hub airport. As a result, the turnaround procedure may be influenced more by time constraints than by the necessity to optimize TAT (Evler et al., 2021).

Large airports nearing capacity may demand standardised TATs for gate allocation and planning purposes. TATs at busy airports can be determined by slot availability. Domestic and international flights may differ due to variances in fuel, catering or luggage requirements (Alonso, 2017). Many typical turnaround procedures, such as disembarkation and loading activities and support services, such as cleaning and catering, may take longer on a widebody, while refuelling may also take longer due to its greater range and fuel capacity. Widebody ground durations for full-service carriers are often determined by commercial scheduling considerations rather than the turnaround procedure.

Due to airline departure schedule, widebodies flying long-haul flights can spend up to 8 hours on the ground. Instead, a rising number of low-cost long-distance carriers may seek to minimise ground time and maximise utilisation. Because of the higher complexity of hub airports, turnaround times are longer than at smaller regional airports. A typical LCC TAT in a provincial rural airport may be 20-25 minutes, but 40-45 minutes for a large hub (AllThingsOnTime, 2022).

The challenge in ground handling resource management is in meeting all requirements whilst dealing with limited resources. Variations in scheduled arrival and departure timings have a significant impact on ground handling expenses and resource allocation. The Scheduled In Block Time (SIBT) or Scheduled Landing Time (SLDT) is one of the key elements on which the whole turnaround process and resource allocations depend. However, for the tactical phase (on-the-day operation) of flight operations, all ground resource planning is completely reliant on the estimated time of arrival (ETA). The estimated time of arrival is crucial element in all ground operations and resource allocations. A more accurate arrival time prediction prior to actual hours of operation will enable the optimum use of ground resources, resulting in cost savings and effective ground resource utilisation. Here, we chose Dubai Airport as a case study to investigate how actual time flight operations differ from scheduled operations and determine how a machine learning-based arrival time prediction could be employed to enhance long-term arrival time prediction.

Flight schedule of the airport is key in planning and executing airlines operation (Wu & Lung, 2005). The flight schedule punctuality problem has generally been studied (Wu & Lung, 2016) using conventional statistical analyses, which can only provide necessary information and most of the studies were based on passenger and airline perspectives. Because of the existence of several agencies, aircraft delays may be caused by several circumstances; moreover, any disruption in the air traffic system can result in additional delays for flights, affecting multiple airports and carriers. Bubalo and Gaggero (2021) and Evler et al. (2021) proposed a mathematical optimization model that incorporates key features from turnaround target time prediction, passenger connection management, tactical stand allocation and ground service vehicle routing into the airline hub control problem. This model is an adaptation of the Resource-Constrained Project Scheduling Problem (RCPSP).

In general, there are two research methods for delay prediction: delay propagation and data-driven methods. Methods based on delay propagation investigate the phenomena of flight delay propagation inside air transportation networks and seek to forecast delays by using the network underlying mechanism. Wu and Law (2019) introduced a Bayesian network-based (BN) flight delay and delay propagation model that uses Expectation-Maximization (EM) arithmetic to examine the impacts of arrival-delay and flight-cancellation on departure-delay at various stages. Waltenberger et al. (2018) performed an operational comparison between low-cost and non-low-cost carriers in terms of on-time efficiency, turnaround scheduling, turnaround performance, and block time setting. The data showed that performance is based on aircraft turnaround and having enough time on the ground to absorb delays. Dinler and Rankin (2020) performed a hierarchical regression analysis to investigate the relationship between airport performance and capacity indicators and on-time arrival rates in United States airports.

Data-driven analyses, rather than delay propagation processes, have become very popular methods for flight delay prediction in recent years, owing to the ability to directly apply data mining, statistical inference and/or machine learning techniques (Ding, 2017; Qu et al., 2020, Deepudev et al., 2021; Zhang et al. 2022). Some of the common data-driven methodologies used to predict flight delays include the random forest algorithm, Multiple Linear Regression (MLR), logit probability, artificial neural network and deep learning (Deepudev et al., 2022).

Local and network delay variables are added to characterise the arrival and departure delay statuses of the most relevant airports and linkages (origin-destination pairs). Belcastro et al. (2016) proposed a method for predicting a scheduled flight arrival delay due to weather factors that considers all flight information (origin airport, destination airport, scheduled departure time, and arrival time) as well as weather conditions at the origin and destination airports. In recent years, several research efforts have focused to investigate the core causes of delays and to develop models to detect and forecast future delays, as well as their causes, time, place, size, and likelihood of occurrence (Carvalho et al., 2021). However, because of the stochastic nature of the airspace and aviation traffic, forecasting probable delays is a complex task. Most of the delay prediction may be generally classified as Arrival Time prediction and Departure Time prediction (Thiagarajan et al., 2017), with the delay propagation term connecting the two. Because most arrival and departure flights are directly linked, predicting departure time fluctuation is more difficult than predicting arrival time variation.

Guleria et al. (2019) suggested a multi-agent strategy for determining reactionary delay based on aeroplane departure categorization as delayed or non-delayed. The classification demonstrated an overall accuracy of 80.7% with a delay classification criterion of 15 minutes. Eurocontrol used machine learning approaches to increase the predictability of take-off times (Codina et al., 2019) for the Maastricht upper area control centre area. The forecasts were based on 3 years of historical flight and meteorological data, and the Mean Absolute Error (MAE) for take-off time prediction was 7 minutes. Ye et al. (2020) used supervised machine learning approaches to provide a framework for forecasting aggregate aircraft departure delays at airports, and they analysed individual flight data and meteorological data to derive four kinds of airport-related aggregate characteristics for prediction modelling.

A few studies have considered early departures (departing sooner than expected) as a probable outcome of airline schedule time padding, which might cause future leg departures to leave earlier than intended (Esmaeilzadeh & Mokhtarimousavi, 2020; Kim & Bae, 2021). In reality, some aggregate features influencing flight schedules and airport delays have not been thoroughly investigated due to lack of data and precise weather information. To account for expected delays and enhance on-time performance, aircraft operators often include a buffer gap in their timetables (Deepudev et al., 2020).

So far, no prior studies have considered the influence of the landing schedule and its fluctuations on the workload of ground personnel (Airport, 2020). In general, airport/airline ground personnel may be classified into two categories based on their affiliation (Offord, 2016). The first category consists of airport ground personnel who are all involved in aircraft fuelling, luggage offloading, and security inspections. When several large flights carrying many passengers are assigned to landing slots in close succession, the workload of all operators can drastically increase, leading to an increase in passenger waiting queues as well as additional manpower, consequently rising operational expenses (Kafle, 2016). Conversely, if a series of light aircrafts with few passengers arrives, there will be idle time. The second group of airport/airline ground workers is responsible for activities such as catering supply refilling, aircraft cleaning, and maintenance checks. In this case, consecutive landings of planes from the same airline (particularly those carrying many passengers) mixed with periods without landings from the same airline result in high workload and idle time. Consequently, it is essential to devise landing schedules that result in balanced workloads for ground workers, while also determining any variations in these schedules (Boysen et al., 2011). Even if the services are subcontracted, the airport and airlines will benefit from balanced workloads since the cost savings should result in lower service pricing. In order to yield such balanced workloads based on schedules, airlines/ground handling teams identify a target rate (number of flight movements per hour) based on the assumption that planned passenger arrivals and/or landings can be evenly spread over the planning horizon, so that actual landings should approximate this rate as closely as possible (Boysen et al., 2011). However, in practise, this will vary, particularly depending on the incoming flight delay. A more accurate target rate must be determined well in advance in order to achieve adequate workload balance and optimal ground resource use.

Objective of this research

1. Identify the impact of variation in schedule and actual arrival time on Airport Ground Handling Resource utilisation.
2. Determine how machine learning-based Arrival Time prediction can optimise Airport Ground Resources and cost-effectiveness.

2. Methodology

We use a machine learning-based model based on feature engineering using minimal number of attributes to predict the estimated arrival time of each aircraft. The model will then offer a future hourly flight information as input and extract resource requirement as expected outcomes on the arrival time. Initially, we conduct extensive data analysis to determine the critical elements in ground-resource allocation. The proposed method provides a more accurate arrival time on the day of operation based on the departure time from the same airport, allowing ground handling service providers to identify the appropriate number of staff every day to cover the tasks required to serve future flight schedules daily based on the flight.

2.1. Data Analysis

We used data on scheduled and actual movement of flights operated to and from Dubai Airport from October 2021 to October 2022. The data was extracted from Flightradar24 (https://www.flightradar24.com). We first compared scheduled hourly flight movement to actual flight movement. For this analysis, we utilised the scheduled and actual flight arrival and departure times for every hour of the day.

Figure 1 shows a detailed comparison of hourly departure flights planned as per schedule with actual departures from Dubai International Airport for each day. Figure 1 also shows that, the number of flights handled every hour varies significantly between scheduled and actual movement. This will result in variation in ground resource requirements over the day, as certain ground resource requirements will remain until the flight departs. This will have an impact on the arrivals for which ground resources are assigned, and it may also introduce delays in service for the arrival of subsequent departures if the ground handling resource planner is unable to foresee such requirements. A similar comparison was made for arrival flights in Figure 2.

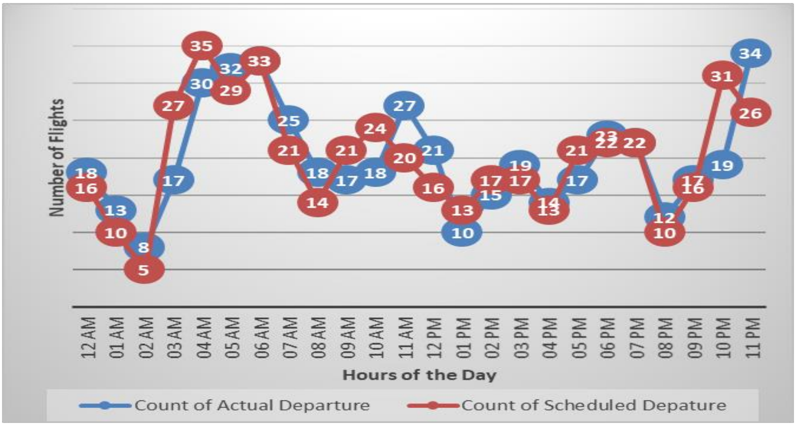

Figure 1: A sample comparison between number of scheduled flight departures and actual flight departures during the hours of a day at Dubai International Airport (Based on data from Flightradar24).

Figure 2 shows that the actual number of arrivals differs considerably from the schedule most of the time. Typically, the ground handling crew plans for future flights well in advance; most airports have arrival flights followed by departure flights termed a bank, which results in large peaks in airport resource demand (Wheeler & Colin, 1989). Most evaluations use resources for flight scheduling to generate demand curves, which are frequently insufficient in real-time. In certain cases, tasks may be linked to flight locations. The flight position is important in defining the resources available; there are numerous types, such as a hard stand or a tube stand. The flight delay or early arrival will result in a revised stand allocation and resource planning.

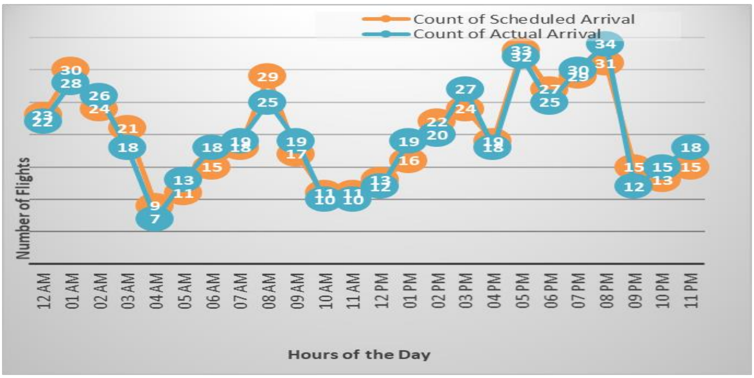

Figure 2: A sample comparison between number of scheduled flight Arrival and actual Arrival during the hours of a day at Dubai International Airport (Based on data from Flightradar24).

Figure 3 illustrates a comprehensive view of scheduled and actual flights arriving between 00:00-08:00 hours. The graph shows that the number of scheduled flight arrivals and actual flight arrivals vary substantially depending on the hour of day. Consider the first hour (01:00-01:59 hours), when 30 arriving aircraft were scheduled for the hour and 21 flights landed on the same hour. The remaining 6 flights landed between 00:00-00:59 hours, with two flights landing between 02:00-02:59 hours and 1 flight landing between 23:00-23:59 hours. Such flight delays (both early and late from the scheduled time) potentially result in significant variations in ground resource mobilisation and simultaneous ground resource requirements at different hours of the day. It can also be inferred from Figure 4 that, the shift in number of aircraft resulted in variation of fleet combination scheduled for the hour and this will result in fluctuations in ground resource requirements.

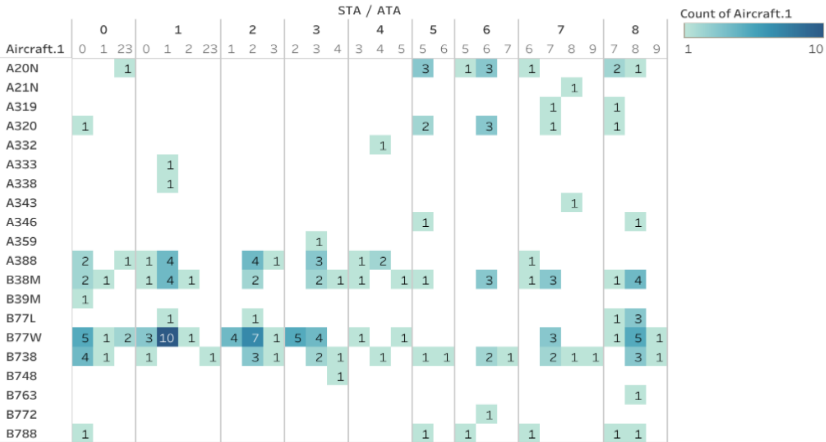

Figure 3: A comparison between number of flights scheduled as per STA and actual number of flights landed as per ATA between 00:00 and 08:00 hours.

We then analysed aircraft-specific arrival time variation to assess the impact of actual and scheduled flight time variation. We classified the difference between actual flight arrival and scheduled flight arrival time. If the difference between actual and scheduled arrival time is more than 15 minutes, it is classified as 'Delay'; if the difference between actual and scheduled landing time is less than -15 minutes, it is classified as 'Early'; and if the flight arrives within +/-15 minutes of the scheduled time, it is classified as 'On time'. Initially, we examined the most frequent type of aircraft operating at Dubai Airport for 3 days and computed total schedule temporal variations (On time, Early, and Delay) using the above classification criteria. We then analysed aircraft-specific arrival time variation to assess the impact of actual and scheduled flight time variation.

The distribution in Figure 4 shows that more than 70% flights are either 'Early' or 'On time' in most aircraft types. However, because the departure schedule time is dependent on the departure schedule/slot, the aircraft may occupy the bay for an extended period and various ground resources teams (ladder, boarding, AMEs, Auxiliary Power Unit) may provide additional service time to specific aircraft. This will also affect the operational efficiency and productivity of ground handling resources (both human and equipment) in most aircraft types.

Figure 4: Arrival time variation (Ontime, Early and Delay) for different category of aircraft.

One of the key consequences of delayed arrivals and departures is the allocation of aircraft stands in remote locations. If the ground resource planner distributes resources to an adjacent bay and the delayed arrival apron management allocates a stand at a remote location, service delay will be imposed. All these factors have an impact on operational efficiency and underutilization of airport resources, which motivated us to employ machine learning to predict arrival time and improve stand and resource allocation. In this study, we also examine the utility of a linear regression model in predicting exact landing/arrival time for each flight based on flight departure time from the same airport. This will allow the ground resource management team to assign resources to the same aircraft based on its departure time and utilize optimal ground resource requirements for the specific hours, as well as a future efficient stand allotment strategy.

2.2. Arrival time prediction

A Turnaround Management system must consequently be able to determine the Target and Actual Times for every Ground Handling (sub-)process. The essential data collecting on the various actions taken by service providers (or internal airline departments) during ground handling is perhaps the most important and challenging element of establishing a competent Turnaround Management system. Figure 5 shows Overall Gantt Chart Schematic for Turnaround Time and the Impact of Flight Time Variation. If the Actual Time of Arrival (ATA) is within a tolerance value (decided by the operator /regulator) of +/-15 minutes of the Scheduled Time of Arrival (STA), we consider it on time and the corresponding departure actual time of departure (ATD) is within a tolerance limit of +/-15 minutes of the Scheduled Departure time, we can consider it on time and it is indicated in green turn around. When the arrival is delayed, there is a potential that the entire turn around procedure will be delayed, which we refer to as the critical turn around process. If the inbound aircraft is delayed and the scheduled padding time (the extra buffer time between arrival and departure) is insufficient, the outbound flight will be delayed. Figure 5 shows that, when the arrival time varies the turnaround process will be affected by ground resource management. This will also significantly affect various procedures involved in the turnaround (de-boarding, cleaning, catering, fuelling and, boarding), showing which of these activities are affected by the delay and how these processes might cause further delays in departure.

As noted earlier, we used regression models to predict return arrival time based on departure time from the airport under consideration. We examine a Multiple Linear Regression (MLR)-based model that is more successful in predicting arrival time. We used the MLR regression model to predict arrival time based on departure time from the same airport (for example, based on the departure time from Dubai airport, the same flight's return arrival time at Dubai Airport would be predicted based on historical data).

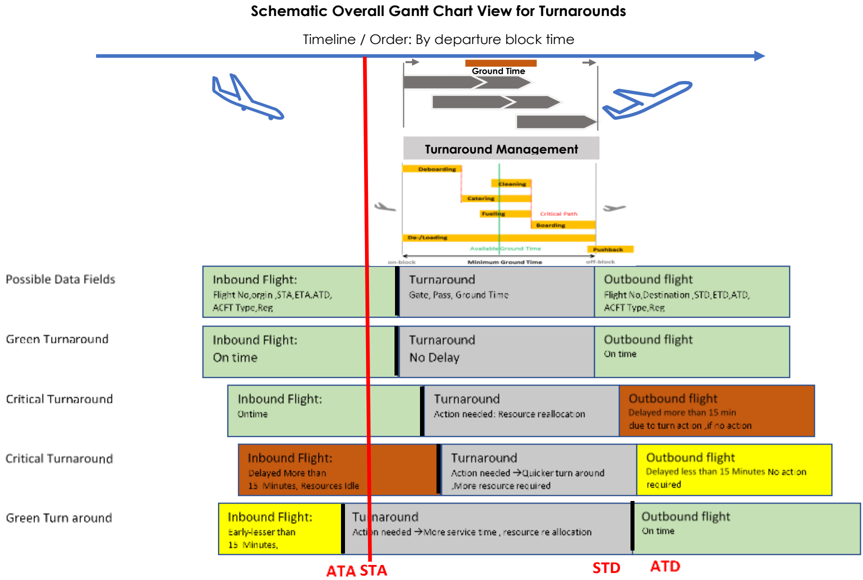

Figure 5: Schematic Overall Gantt Chart View for Turnarounds with Ontime Delayed and Early Arrivals with its impacts on turnaround time and Outbound flight.

2.3. Multiple Linear Regression (MLR)

Linear regression is a modelling technique for analysing data to make predictions (Tranmer & Mark, 2008). In this study, we consider the landing time prediction problem as a regression problem. The Linear regression model fits a linear equation from observed data between the dependent variable (Y) and input independent variables (X). If a single independent or explanatory variable is used for modelling, then the process is called Simple Linear Regression. For more than one independent variable, the process is called Multiple Linear Regression. Linear models are relationships modelled by linear predictor functions, which estimate unknown model parameters from the data. It allows the estimate, E[Y] to depend on more than one independent variable and to have shapes other than straight lines, although it does not allow for arbitrary shapes.

2.4. The Feature engineering

The backward elimination approach was used for feature engineering, and categorical variables were converted to numerical variables using the one-hot encoding technique. Actual departure time, departure delay, aircraft type, aircraft registration, exponential moving average of previous flying time (derived feature), scheduled flying time outbound leg, scheduled flying time inbound, and hours of the day are the features used for the MLR model.

3. Results and Discussion

The analysis was carried out to predict different segments of multileg flights. Initially, we analysed the prediction capability of the proposed method for predicting the landing time of the two legs using Departure time variation, Aircraft type, Hours of operation, Destination, Aircraft registration, exponential moving average of flying of previous flights, scheduled flying time for both outbound and inbound. The data was split into training (80%) and test set (20%). The MLR model was developed by 10 folds cross validation. The performance of supervised learning models for predicting landing time was evaluated using Root Mean Squared Error (RMSE) and the model predicted the Arrival Time with an RMSE of 8.01 minutes. This indicates that, under normal operating conditions, based on the departure time from Dubai Airport, the same flight's arrival time (return from destination airport) to Dubai Airport can be predicted with an accuracy of 8 minutes. A sample of prediction results using test data for a scheduled flight operated between Dubai (DXB) International Airport, Jakarta International Airport (CGK) and return to Dubai International Airport on different days are shown in Table 1. The last column (Predicted _ATA) in Table 1 represents the arrival time predicted by the proposed model, whereas ATA_2 provides the actual arrival time and STA_2 represents the scheduled arrival time. A similar analysis was carried out for flights from Dubai (DXB) to Paris (CDG) and returning to Dubai, and the ETA was estimated with an RMSE of 10.2 Minutes.

ID	DATE	Orgin	Dest	Aircraft	Flight Time	STD	ATD	Dep Delay_1	ID_2	Dest_2	Flight Time_2	STA_2	ATA_2	Predicted ATA_2
XX	25/09/2022	DXB	CGK	B77W	08:02:00	00:10:00	00:37:00	27	XY	DXB	07:15:00	18:55:00	18:19:00	18:30:00
XX	24/09/2022	DXB	CGK	B77W	08:04:00	00:10:00	00:26:00	16	XY	DXB	07:11:00	18:55:00	18:29:00	18:24:00
XX	23/09/2022	DXB	CGK	B77W	07:58:00	00:10:00	00:26:00	16	XY	DXB	07:13:00	18:55:00	18:14:00	18:15:00
XX	22/09/2022	DXB	CGK	B77W	08:02:00	00:10:00	00:39:00	29	XY	DXB	07:12:00	18:55:00	18:13:00	18:18:00
XX	21/09/2022	DXB	CGK	B77W	08:06:00	00:10:00	00:22:00	12	XY	DXB	07:11:00	18:55:00	18:17:00	18:21:00
XX	20/09/2022	DXB	CGK	B77W	07:54:00	00:10:00	00:24:00	14	XY	DXB	07:18:00	18:55:00	18:28:00	18:27:00
XX	19/09/2022	DXB	CGK	B77W	07:49:00	00:10:00	00:21:00	11	XY	DXB	07:22:00	18:55:00	18:22:00	18:30:00
XX	18/09/2022	DXB	CGK	B77W	07:55:00	00:10:00	00:28:00	18	XY	DXB	07:21:00	18:55:00	18:24:00	18:20:00

Table 1: Scheduled flight movement details with predicted arrival time.

Our findings showed that, better feature engineering, using MLR model was able to predict the arrival time with 10 minutes of variation before 14-16 hours (for example, in Table 1, destination airport is located at around 7 hours flying time) of actual arrival time of the scheduled flight. The MLR model was able to predict the variation in arrival time based on historical travel time and its temporal variations. This will enable the ground resources management team to optimally deploy resources and determine hourly traffic density well in advance. Based on data analysis, we observed that around 50% of scheduled flights originating from Dubai to other airports return to Dubai after a normal turnaround time since it is a hub airport, making prediction of next arrival time from departure time of same airport practically achievable.

4. Conclusion

Even though flight schedules are predetermined, flight delays are unavoidable for several reasons, some of which are not human related. These delays cost the aviation industry. One major challenge the aviation industry encounter is early detection of the occurrence of flight delays so that proactive measures can be adopted to minimize their impact and costs, especially in ground resource management. We proposed a hybrid machine learning model with exponential moving average to predict arrival delays, especially in round-trip flights. The model was used to calculate reactive arrival delays in aircraft itinerary, which arise as a result of turnaround interval and arrival delays encountered by flights. To efficiently trace temporal stochastic fluctuations, the proposed model used an exponential moving average of various flight segments. In contrast to previous studies, more accurate and reliable arrival time predictions for multileg flight operation would result in informed decision making and resource planning. The proposed model can predict landing time with an RMSE of 8 minutes using a minimal number of attributes, making the approach practically feasible for deployment. A more accurate arrival time prediction based on machine learning approaches will enable the ground resources management team to optimally deploy resources and establish hourly traffic density well in advance, making ground resource optimisation practically feasible. The robustness of the model was validated using various departure destination pairs and diverse types of aircraft. Future research in this area will broaden the current framework to include other complex airport-based characteristics such as runway changes, arrival data, equipment outages, wind speed effect, delay propagation, gate allocation and their effects on departure delay, as well as predict hourly traffic density with fleet mix and estimate ground resource requirements.

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